DOCUMENT RESUME

ED 210 146 SE 035 764

AUTHOR	Baldwin, Lionel V.; Down, Kenneth S.
TITLE	Educational Technology in Engineering.
INSTITUTION	National Academy of Engineering, Washington, D.C.
REPORT NO	ISBN-0-309-03138-9
PUB DATE	81
NOTE	110p.: Appendices A, B, and D, pages 99-112 and 117-125, removed due to copyright restrictions.
AVAILABLE FROM	National Academy Press, 2101 Constitution Ave., N.W., Washington, DC 20418 (no price quoted).
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	Audiovisual Aids; College Science; *Communications Satellites; *Computer Oriented Programs; *Educational Media; *Educational Technology; *Engineering Education; Higher Education; Instructional Materials; Program Descriptions; Program Evaluation; Science Education; *Videotape Recordings

ABSTRACT

A critical evaluation of the educational technology literature with respect to its application to engineering is provided. Although the major emphasis is on videotape systems, other technologies discussed include satellite applications and video/computer combinations. A number of suggestions are made throughout the report and are summarized in a final section. (Author/SK)

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educational technology in engineering

Prepared by
Lionel V. Baldwin **and** *Kenneth S. Down*
for the
National Academy of Engineering

NAS NAE IOM *National Academy Press*

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NATIONAL ACADEMY PRESS
Washington, D.C. 1981

SE 035 784

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Library of Congress Catalog Card Number 81-80333

International Standard Book Number 0-309-03138-9

Available from

NATIONAL ACADEMY PRESS
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

FOREWORD

Since its founding, the National Academy of Engineering (NAE) has taken a major interest in engineering education. For several years there was a Council on Engineering Education which produced much work including an early report summarizing available educational films in the engineering area. Even though this document is out of print, we still receive occasional requests for it.

In 1978, the NAE formed an ad hoc committee on Advanced Technology in Engineering Education. At that time, an excellent treatise on educational technology in engineering was prepared by Dean Lionel V. Baldwin of Colorado State University and Associate Dean Kenneth S. Down of Stanford University. The obvious utility of this document led us to ask the authors to update the material in order that we could make it available to the many people interested in this important subject.

C. D. Perkins

Courtland D. Perkins
President
National Academy of Engineering

PREFACE

This paper reviews the literature and current knowledge on the use of modern technological methods in engineering education with an emphasis on videotape systems. The primary focus is on current practices. In the concluding two chapters, we make a critical evaluation of today's activities and offer some recommendations for future activities.

We do not attempt to summarize the many reports concerning educational technology which offer rationale for government action. The National Academy of Engineering is clearly addressing the correct issue: how to improve the quality of engineering education.

No pretense is made that this report is complete, but we hope it offers a representative sampling of good practice today. The authors would welcome comments. The authors also would like to express their appreciation to Linda L. Jenstrom for her editorial assistance in preparing this manuscript.

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ABBREVIATIONS

ACE	Association for Continuing Education
ACS	American Chemical Society
AMCEE	Association for Media-Based Continuing Education for Engineers
ASEE	American Society for Engineering Education
BBC	British Broadcasting Company
CAD	computer-aided design
CAES-MIT	Center for Advanced Engineering Study, Massachusetts Institute of Technology
CAI	computer-assisted instruction
CAM	computer-aided manufacturing
CATV	cable (television) delivery systems
CMI	computer-managed instruction
CPA	Certified Public Accountant
CSU	Colorado State University
DISCUS	Disposal and Collection User Simulation
DOE	Department of Energy
ECPD/ABET	Engineer's Council for Professional Development/ Accreditation Board for Engineering and Technology
EIT	Engineer in Training
ET	educational technology
ETV	educational television
FCC	Federal Communications Commission
IEEE	Institute of Electrical and Electronics Engineers
ITFS	instructional television fixed service
ITV	instructional television
MIT	Massachusetts Institute of Technology
NAE	National Academy of Engineering
NASA	National Aeronautics and Space Administration
NIE	National Institute of Education
NPR	National Public Radio
NRC	National Research Council
NSF	National Science Foundation
PBS	Public Broadcasting Service
PLATO	Programmed Logic for Automatic Teaching Operations

PSI	personalized system of instruction
RIT	Rochester Institute of Technology
RPI	Rensselaer Polytechnic Institute
TICCIT	Time-shared Interactive Computer Controlled Information Television
TVI	tutored videotaped instruction
USC	University of Southern California

SUMMARY

Educational technology (ET) encompasses not only the use of materials and hardware to aid in the learning process, but also the systematic organization and presentation of knowledge to the learner. The rejuvenated interest in ET today stems from the microelectronics revolution of the past decade which, coupled with the development of digital and laser systems, is just starting to produce useful instructional hardware that is more powerful and more affordable. Indeed, some items are intended for direct consumer purchase.

The challenge of devising appropriate ways to employ hardware in education is stressed throughout this paper. Much of the text focuses on effective examples of ET as it is practiced in engineering education. The recommendations, presented after this summary, call for new programs which would capitalize on the decentralization of the new, inexpensive, stand-alone ET delivery systems.

Three major goals for introducing ET are: 1) to save dollars; 2) to enrich, improve, and individualize instruction; and 3) to serve the unserved or enlarge coverage. By documenting the specific goals and results of ET applications in the economic context of productivity, educators could describe a wide array of goals for ET in terms readily understood by those who make policy. Actual examples of courses are used to illustrate the productivity concept; situations in which additional outputs are identified that justify the additional input of ET are described.

Instructional television (ITV) in engineering education on campus is often not popular with undergraduates when it is substituted for live lectures. Early ITV uses were viewed as too impersonal by many students. Yet, through careful implementation, ITV can demonstrably enhance learning, and, at the same time, lower the cost of instruction. The first course in accounting at Colorado State University is an excellent example. This course is built around 20- to 25-minute lectures which are studio produced, well illustrated, and continually revised. Groups of approximately 30 students viewing a brief ITV lecture are proctored by graduate teaching assistants. Immediately afterwards, the assistants lead discussions and interactive problem-solving sessions. In each of the past 14 years, over 500 students have been exposed to standardized content in relatively small classes at less than $1.50 per student-contact-hour. These students consistently score in the top 25th percentile of the national Certified Public Accountant (CPA) examination for Level I, beginning accounting. The key points that have made the course a success seem to be: simplicity of presentation and active participation by the students.

Today, many engineering faculties are faced with record numbers of students. Problems such as having to teach very large classes and having to turn away students are commonplace. Properly applied, ITV could be a cost-effective alternative, yet it languishes on most campuses. More efforts to achieve both effective and popular applications are required.

Included among the more popular applications is the instant replay of classroom lectures under the guidance of a tutor. Such a program is used by the Massachusetts Institute of Technology to stem the attrition of ethnic minority undergraduates. Lecture review by way of cable delivery systems (CATV) to dormitories and to library self-study carrels also is popular. Some experiments involving the use of videotape in self-paced instruction show promise.

Student performance in oral and written communication skills has been improved by audiotape and videotape experiences. Individual laboratory reports are critiqued by Southern Methodist University instructors using audio cassettes in a very personal, effective manner. The opportunity to view one's own presentation by videotape replay and to be coached by peers and teachers in needed improvements is clearly valuable.

In other universities, non-scheduled or open laboratory hours are made possible by files of videotapes which describe the purposes of experiments and demonstrate the procedures to be followed. Through films or videotapes, it may be possible to simulate some laboratory experiences; however, to date, only instructors in fluid mechanics have made wide use of this method. Many industrial machines and processes which cannot be duplicated on campus might be subjects of well-designed videotape presentations.

The case study method of instruction is gaining favor as an effective way of introducing students to realistic design problems throughout the engineering curriculum. ITV can add realism and emotional stimulation to this method. Good prototypes are cited which involve human factors in systems design and in professional ethics courses. However, much more needs to be done in this area.

The greatest impact of ITV in engineering education to date has been in its off-campus applications. During the past decade, approximately 30 universities have developed regional ITV systems which today provide regular graduate classes originating from campuses to over 44,000 engineers at their job sites. These programs are popular, effective, and continue to proliferate. No federal funds are involved. Rather, these ITV systems are local responses to a professional need and are paid for by industrial and government employers.

Recently, 22 universities, which account for over 85 percent of the off-campus ITV instruction, joined together to form the Association for Media-Based Continuing Education for Engineers (AMCEE). The goal of AMCEE is to increase the national effectiveness of continuing education for engineers. Work is underway to distribute videotaped courses nationally (over 450 courses from 22 universities were cataloged in 1980) and to develop special workshops and seminars on timely topics. The emergence of videopublishing offers the university a unique opportunity to serve the practicing professional.

There are examples of television employed in engineering education at junior colleges, high schools, and in foreign locations. These show considerable promise, but, unfortunately, they are rare.

The use of satellites offers a unique opportunity to develop both nationwide programs and resource sharing with foreign educators. The engineering profession brings a background of tried and tested educational services to the "new" communications technologies. Experiments have already shown that use of satellites could overcome three current types of problems in ITV operations: technical, i.e., the ITV signal can travel only a short distance at a reasonable cost; logistical, i.e., the mail and other delivery services are slow; and financial, i.e., a videotape inventory is expensive. In addition, unique features such as teleconferencing could assist in the co-management of education tasks both between U.S. industries and universities and between foreign universities and U.S. universities. The domestic applications have been studied in detail by AMCEE; satellite delivery of ITV could break even financially two to four years from initiation if capital were available for the ground facilities.

The very recent advent of personal computers and inexpensive videodisc systems, coupled with microprocessors, is stimulating renewed interest in computer-assisted instruction (CAI). University presidents may welcome this consumer "takeover" of computing. During the 1976-77 academic year, $991 million was spent on computers for universities. About three-quarters of this amount came from university funds, and the remainder was primarily supplied by federal agencies. Fewer than 50 engineering colleges recently reported some use of CAI, but virtually all (238) reported use of computers for problem-solving activities.

Very few educators have the experience necessary to make effective use of the new CAI hardware immediately. The first task is, therefore, to enlarge the group of engineering and physical science faculty who study and test the potential of the medium in small working groups at many universities. Like all technology, ET requires key human resources for implementation. The appropriate adoption of ET is seriously hindered by the historical lack of a broad-scale, sustained effort to enlarge the number of talented individuals working with media.

The greatest payoff of the new hardware in engineering education will be attained through interactive computing combined with graphics. These can provide unique learning experiences that will develop skills in synthesizing and analyzing, as well as assist in visualizing, thus developing intuitive skills. Applications of computer-aided design (CAD) and computer-aided manufacturing (CAM) need to be introduced virtually in all of the engineering colleges that today lack the instructional facilities to serve students properly. This is a pressing, massive problem; it needs to be addressed squarely.

The rapid introduction of measuring instruments that incorporate microprocessors and digital memory is widening the gap between industrial practice and university laboratories. The emergence of these powerful new instruments and control devices is outpacing the equipment budgets of universities. Traditional laboratory procedures are being changed fundamentally by the built-in data analysis programs of the instrumentation. Unlike most of the ET discussed in this report in which courseware is the dominant issue, the instrument revolution described above is essentially a hardware problem.

Suggested Actions

Educational technology today offers many attractive investment opportunities. Successful applications of ET in engineering education involve faculty who have both an educator's insight into pedagogical issues and an engineer's skill in organizing and adapting hardware. Perhaps no better proving ground for instructional technology could be devised.

The primary purpose of this report is to provide a critical evaluation of the ET literature with respect to its applications to engineering education. A number of suggestions are made throughout the report and are summarized in Chapter V in the hope that they will serve as stimuli for thoughtful consideration and, perhaps, even action. The authors' principle suggestions, listed in order of priority, are:

- Government agencies should design funding programs which encourage broad-scale, diversified development and testing of ET courseware in various media at the local course level. Although some basic instructional research in artificial intelligence and other, similar areas should be funded, major support should be given to improving local courses and to productivity studies. The purpose of these programs would be to involve many more faculty, nationwide, in meaningful ET activities.
- At least twelve prototype computer graphics centers should be funded in the next two years at selected engineering colleges. These centers would serve as regional models for the organization and operation of interdisciplinary facilities, as clearinghouses for vendors and educators, and as developers of outreach materials for engineering educators nationwide. External funding of these pioneering centers might require one-third to one-quarter local matching funds. A second round of facility grants to ensure the general availability of computer graphic equipment might involve as much as a 50 percent match by colleges and universities.
- Several university videopresses should be endowed at universities having both a strong commitment to continuing education of professionals and the media expertise to set high

standards of quality. These new enterprises would provide a creative outlet for faculty everywhere and encourage the development of modern instructional programs under the guidance of skilled staff.

- An operational plan to test the cost effectiveness of communications satellites should be funded to provide engineers with the following educational services at their job sites: national delivery of graduate credit courses in a coordinated program initially involving 10 AMCEE universities; delivery of continuing education short courses; and teleconferencing between originating sites to provide for direct faculty exchanges, special seminars, and technical meetings. Studies should be undertaken to involve ethnic minority colleges of engineering in activities of their choosing.
- Post-graduate study programs offered by U.S. engineering colleges might be transmitted overseas via satellite. The potential advantages of high-quality educational opportunities available in the homeland of the student may warrant the investment necessary to employ modern communications technology.
- An in-depth study of the equipment problems of colleges of engineering should be undertaken, perhaps by an industrial team sponsored by the National Research Council. Recommendations might include government incentives to industry, as well as emergency programs to overcome what has become a massive problem of hardware acquisition.
- Federal agencies should design a number of new programs to expedite the transition to decentralized computing. These diverse efforts might include sponsorship of the following: consumers' unions to evaluate machines and courseware; visiting lectureships; workshops and summer institutes; and media-based, packaged, short courses for in-service training of teachers.
- Foundations should explore the creation of working consortia or nonprofit organizations to produce high quality films and videotapes in support of case study instruction, especially in engineering design and in professional ethics.
- The use of ET in attracting, motivating, and preparing ethnic minority students and others who are educationally disadvantaged in grades 9 through 12 should be extended. A few university-based centers could supply materials and information to the many programs which are now sponsored by businessmen and educators regionally.
- The National Academy of Engineering (NAE) should sponsor a feasibility study on the creation of several regional computation centers for engineering research.
- The NAE should update its 1974 study on issues and public policies in ET in the light of current trends and forecasts in hardware delivery systems.

I.
EDUCATIONAL TECHNOLOGY

The promise of technology in the educational process at all levels has never been greater than it is today. The reason is clear: the microelectronics revolution of the past decade, together with digital and laser system development, is just starting to bear fruit in useful instructional hardware. The cost of such hardware continues to decrease and may soon be an insignificant impediment. Now, the challenge of devising appropriate ways to employ hardware in education is brought into sharper focus.

Educational technology (ET) encompasses two aspects: the organization of knowledge for learners; and the use of materials and machines to aid in the learning process. Educational technologists are those who seek to apply scientific and other organized knowledge to the practical tasks of education. These creative practitioners endeavor to understand learning theory and to apply it. They often are viewed by their peers as reformers, even revolutionists. However, perhaps most fairly, many ET activists are proselytizing optimists! Their optimism now seems warranted since more ET alternatives are rapidly becoming affordable.

For a variety of reasons, however, the practice of ET falls short of the promise envisioned by some people. Cost is often cited today as a major impediment to computer-based instruction. Yet, economically attractive alternatives such as some forms of instructional television (ITV) have not gained universal acceptance. The effectiveness of ET varies from situation to situation, but ET is often on par with traditional methods. Lack of wide acceptance of ET is sometimes traced to conservative institutions of higher education in which, it is argued, neither faculty nor administrators have the appropriate experience and knowledge needed to introduce ET effectively. Continuing this line of thought, some ET enthusiasts state that traditional schools are obsolete and that ET can, in principle, provide educational services to widely dispersed learners in a time-independent manner. More thoughtful educators argue that the premise that suitable ET is readily available today is incorrect. The delivery devices may be purchased perhaps, but instructional materials are rarely marketed. Furthermore, the development and introduction of ET should be matched carefully to learner needs. ET extremists are viewed as classical examples of technologists in search of problems.

The literature review which follows focuses on ET in practice, starting with a brief historical overview. The body of the material is organized by specific delivery technologies, i.e., video, computer/video combinations, and communications satellites. Under each technology, illustrative examples of applications in various settings are presented. Where available, evaluative and economic data are cited with each example. Because this report covers a wide range of materials, readers seeking information on a specific topic should first scan the Table of Contents.

The core of the ET organizational problem is fundamental: all learning is individual, even in group instructional settings; individuals vary greatly in characteristics; and the behavior of each person may vary over time and be subject to complex environmental influences. David Hawkridge, Director of the Institute of Educational Technology of the Open University of the United Kingdom, states the problem candidly:

> One of the questions I am frequently asked by visitors to the Open University is, "How do you choose which media to use for different parts of your multi-media courses?"
>
> I feel that I am expected, in answer, to point to a beautifully constructed algorithm and explain how a carefully balanced analysis of pedagogical factors leads to the best choice. In fact, I have to admit that no such algorithm or analysis exists, and that the University's selections of media are controlled by logistical, financial, and internal political factors rather than by soundly based and clearly specified psychological and pedagogical considerations.
>
> I don't like admitting this: it seems as though it is not to the credit of the University, a leader in the multi-media field. But, I don't feel too defensive about it. The fact is that instructional researchers and designers have not provided even the foundations for constructing strong practical procedures for selecting media appropriate to given learning tasks. If there has been British work in this area, I have been unable to discover it. . . . In the United States, over 2,000 media studies have not yielded the answers we need. (Hawkridge, n.d.)

Infancy of ET: 1950 to 1965

Hawkridge (1976) captures the spirit of ET in practice. He reviews the conceptual framework from the point of view of an educational psychologist, and, in a lively fashion, puts today's efforts into historical perspective. He notes that Skinner's (1954) principles for teaching machines, including programmed texts/machines, were the hallmark of ET in its infancy:

- Reinforce the student's responses frequently and immediately;
- Provide for the student to be in control of the learning rate;
- Make sure the student follows a coherent, controlled sequence; and
- Require participation through responding.

Programmed instruction has a small but dedicated following among engineering educators. One technique, which generally follows these principles, has gained wide acceptance in engineering education. This pedagogy, personalized system of instruction (PSI), is discussed in detail later, but the close relationship between PSI and early educational research is worthy of note. In citing Hartley's (1974) systematic review of research on programmed learning, Hawkridge notes: "No method of instruction has ever come into use surrounded by so much research activity."

From 1949 to 1953, a group of college [illegible]fessors interested in educational psychology met annually to develop a taxonomy of behavioral objectives in the cognitive domain. The resulting book, Bloom (1956), has had a significant and continuing influence on curriculum development at all levels. Reference is made to this taxonomy in the later discussion of computer-based instruction for engineers.

During this early period, researchers in psychometrics refined testing methods along two lines, norm-referenced and criterion-referenced testing. Hawkridge (1976) observes that "a full understanding of the differences between the two types of tests has continued to elude many [ET] practitioners." Norm-referenced tests are intended to show where a student stands in relation to a peer group, and, in many cases, the statistical work behind the test development assumes a normal distribution of ability among students. Criterion-referenced testing, on the other hand, assumes that a given task can be achieved at a given criterion level by all who have been appropriately taught. The latter form is almost exclusively used by engineering educators. There is one notable exception, the nationally administered Engineer in Training (EIT) examination. The EIT is the first step toward registration of professional engineers and is intended, among other things, to protect public safety and welfare. In this light, one might reasonably expect a criterion-referenced test, but, in fact, the current program employs an norm-referenced test. It is safe to say that psychometric research has had little influence on engineering educators.

Adolescence of ET: 1965 to Date

By the mid-1960's, interest shifted from programmed learning to other formats. Hawkridge (1976) found that fewer and fewer programs were written strictly according to Skinner's original prescription.

The pure linear program, consisting of many short frames with a high degree of repetition, was no longer favored. Crowderian branching was inserted into linear sequences more often as pointed out by Lumsdale and Glaser (1960). Hawkridge (1976) notes that "Educators and psychologists were saying that the only machines which stood a chance of succeeding commercially were those which incorporated more than the written word, through using records, tape, or film." The literature of the day talked of multi-media systems design, as well as behavioral objectives.

Computer-assisted instruction (CAI) was slowly gaining supporters. During the mid-1960's, for example, most engineering colleges had only central, batch operated computers available, and, in many locations, the selection of equipment and its operation was in the hands of administrative data processors. In a benchmark publication (Buchnell and Allen, 1967), the role of computers in higher education was assessed and directions for the future were outlined:

> Some assume (correctly) that the production of time-sharing programs can be quite expensive, and on the other hand, some assume (incorrectly) that time-sharing systems are available as off-the-shelf items. Someday they may be, and a few, such as those of General Electric, almost are. Indeed, most major computer systems eventually will be delivered with at least the framework for a time-shared system, but we should not be overly optimistic about the rapidity with which these can be put into operation. (Buchnell and Allen, 1967)

Nonetheless, work to individualize instruction (CAI) was well underway. A review of the systems and projects (ibid., Chapter 8, Karl L. Zinn) discusses the functions of CAI systems and catalogs 26 major projects then in progress.

If computers in education attracted technical specialists and others who were often favorably disposed to the programmed learning approach, television did not. Films are the natural antecedent of instructional television (ITV), and many of the early practitioners came to ITV from film making. Not surprisingly, artistic values play a large role in the ITV research literature; quality is often judged in the context of the audiovisual impact of the medium. Taking this a step farther, a well-respected producer of ITV programs argues that the printed material should take care of the cognitive aspects of learning and the ITV program should take care of the emotional aspects of the matter (R. Lundgren, Chapter I, in W. Schramm, 1972). Conversely, the "talking head" is synonymous with bad television, because, the argument goes, ITV should have the same stimulating impact that the learner has come to expect from commercial TV. While these attitudes are maintained to this day by an articulate group, ITV in engineering education takes many forms, ranging from inexpensive, candid classroom presentations to expensive British Broadcasting Company (BBC) documentaries. Engineering educators seem not to be influenced by the experimental research on ITV, perhaps because many of the so-called experiments simply are gross comparisons of factual recall by students receiving ITV instruction with control groups of students receiving conventional classroom instruction. Often, this comparison reveals no significant differences even though the attitudes of the students may have been affected significantly.

"In contrast to the hundreds of experimental comparisons of ITV with conventional classroom teaching reported in the literature, there are, at most, a few score of studies specifically on the content and strategies of ITV." (Schramm, 1972) By enriching this data base with earlier studies of films, Schramm concludes "that the research on content variables comes down very strongly on two points which offer useful guidelines to anyone concerned with programming instructional television or film. One of these is simplicity of presentation; the other, active participation by student in the learning experience." (*ibid*.) Appendix A reproduces more conclusions from Schramm's study which should be of interest to engineering educators. These conclusions provide a thoughtful antidote for the film maker's folklore.

The introduction of instructional technology often occurs without an explicit statement of goals. More often than not, the rationale for a given approach in a university is determined either by a single professor or by a small faculty group, which may have multiple, unarticulated goals. At the local administrative level, when specific resources are available, the task is to select the policies, people, facilities, and equipment that will give the students the best and biggest education per buck. Educational technologists argue that the current *ad hoc* practices could be improved by a systems approach, which also often implies a team of specialists working in a closely coordinated fashion (e.g., Pask and Lewis, 1972; or, for research background, Merrill, 1971). Conceptually, the systems approach should be attractive to engineering educators. However, just as a creative engineering designer may proceed through the steps in a systems approach while directing a design project, though perhaps not sequentially, documentation often is sparse, particularly in smaller organizations. A systems specialist may not be available, yet the project is completed. Unfortunately, the engineering educator frequently fails in this respect also. Yet, there is no serious debate about the need for a conceptual framework or the desirability of documentation. The few exceptions in which documentation of a systems approach exists are worth noting; these are drawn from widely differing approaches to engineering education (Rosenstein, 1968; Wales and Stager, 1972; Keller and Koen, 1976).

Economics of ET

The systems approach places appropriate emphasis on an explicit statement of instructional objectives and measurement of outcomes to determine whether these objectives have been met. In this context, policy-makers can view the introduction of technology in economic terms.

Unfortunately, when technology is externally imposed, instructors often fear "automation" of the educational process and interpret this in the coldest possible terms, i.e., operational cost savings by replacing teachers with machines which require only a capital investment (Starke, 1972). There are, of course, many other economically attractive ways to employ technology, but, since these are often poorly understood by administrators and faculty alike, the economic concepts involved remain largely abstractions.

Productivity is a concept related to the amount of output one gets from inputs to a production process (Melmed, 1973 and Haggerty, 1974). Few educators are satisfied with student-credit-hours as the sole output measure for higher education, and rightfully so, because credit-hour production totally lacks a measure of quality. While we appear "stuck" with this proxy in national or macro-economic studies, at the course or curriculum level, better productivity measures are possible. Indeed, it is hard to deny that cost allocations on the input side have reached some degree of sophistication in higher education.

An excellent example of productivity studies which demonstrate the power of the concept and the variety of relationships which can be described in tangible terms is the work of Willey (1975) on instructional computing. Appendix B reproduces these case studies. Productivity is a promising framework for judging the effectiveness of instructional technology. It places a burden on academe to document activity, but it offers an accountability measure understood by policy-makers, or at least their staffs. Educators surely should be interested in the examples that demonstrate that, although computing increased rather than decreased the current costs of instruction, outputs could be identified which justified the additional inputs.

While it is tempting, the argument that these ideas can be readily extended to show that the input combinations chosen for a task are the minimum cost choice, or that we know how to design the most efficient educational program is premature (Jamison, et al., 1974). The dilemma posed by no significant difference in outcome between traditional classroom instruction and various forms of instructional technology is that any search for the most efficient mix of instructional methods surely will be in the direction of the least expensive formats. Yet, few of us would want to endure a regular diet of large lecture courses, perhaps interspersed with inexpensive ITV or PSI. Schramm (1977) examines the issues associated with the selection and blending of instructional technologies in depth, and, while he offers no easy answers, he does offer sound advice to decision-makers at all levels.

Instructional Goals for ET

> In the conviction that technology can make education more productive, individual, and powerful, make learning more immediate, give instruction more scientific base, and make access to education more equal, the Commission concludes that the nation should increase its investment in instructional technology, thereby upgrading the quality of education, and, ultimately, the quality of individuals' lives and of society generally.

> Our study has shown that one-shot injections of a single technological medium are ineffective. At best they offer only optional "enrichment." Technology, we believe, can carry out its full potential for education only insofar as educators embrace instructional technology as a system and integrate a range of human and nonhuman resources into the total educational process. (Tickton, 1970)

A short list of the most common instructional goals for ET in engineering education follows:

- To reduce or contain costs (replace teachers and/or administrators);
- To enrich, improve, and individualize instruction; and
- To serve the unserved or enlarge coverage.

These are not mutally exclusive, of course, and the list might be expanded. The list does indicate, however, the most important objectives for modern technological methods in engineering education.

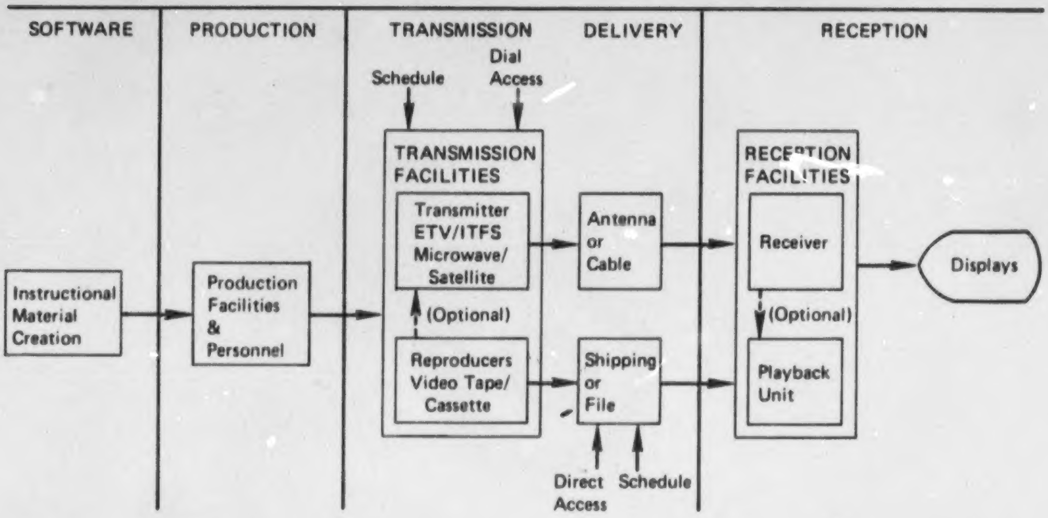
The balance of this brief report will focus primarily on television. In part, the backgrounds of the authors dictate this, but the outcome should not be distorted. The role of computers and computing in education is much better documented in the literature, no doubt because the investment required is massive in comparison to that for television. Furthermore, the videodisc, which stimulates much of the current interest in ET, is exciting because it may offer a hybrid of these media at an affordable cost.

II.

VIDEO-BASED INSTRUCTION

In 1966, an equipment breakthrough occurred in video recorders. Ampex introduced a one-inch videotape recorder/player for about $3,000. The unit delivered good quality displays if properly maintained, though the early machines were only about 80 to 90 percent reliable. Redundance overcame this problem because the price was right. Indeed, the only good quality black-and-white video recorders available prior to this model were priced at $50,000 to $100,000. Several Japanese manufacturers introduced one-half-inch tape recorders in 1967, and, after a brief period, settled on a standard format (EIAJ). These compatible machines sold for about $800, and, like the earlier one-inch tape machines, they required careful maintenance. Sony Corporation introduced a three-quarter-inch videocassette in 1970, inducing other manufacturers to promote compatible units, indeed almost identical machines. Tape handling, head wear, and other maintenance problems were greatly reduced in these units which now sell for $1,000 to $1,500. The fidelity of the recordings and the flexibility provided to the user are both excellent. The most recent recorder to be marketed is targeted for consumer/home use. The one-half-inch cassette units come in two formats, Beta and VHS (the Philips unit is still another); these were first widely offered in 1977 by at least eight manufacturers within a price range of $800 to $1,200. Unfortunately, the two formats are not compatible, and, since various tape speeds are employed as well, this product offers potential problems to the user unless local standardization is enforced.

A block diagram of the major components of an instructional television system (ITV) is shown in Figure 1. The reproducer/playback units are now a part of many systems because of the improved cost/performance cited above. As Figure 1 indicates, a variety of over-the-air systems is employed today by engineering educators. Standard public broadcast facilities for educational television are available on a limited basis in several state-wide systems. Instructional television fixed service (ITFS) is specifically designated by the Federal Communications Commission (FCC) for ITV applications. Operating at a frequency of 2.5 gigahertz, ITFS has


SOFTWARE
PRODUCTION
TRANSMISSION
DELIVERY
RECEPTION
Schedule
Dial Access
TRANSMISSION FACILITIES
Transmitter ETV/ITFS Microwave/ Satellite
(Optional)
Reproducers Video Tape/ Cassette
Antenna or Cable
Shipping or File
Direct Access
Schedule
RECEPTION FACILITIES
Receiver
(Optional)
Playback Unit
Displays
Instructional Material Creation
Production Facilities & Personnel

SOURCE: Hayman and Levin, 1973.

FIGURE 1 Instructional television systems.

4 megahertz bandwidth with up to 40 broadcast channels set aside. In 1980, however, the FCC proposes to lower this allocation. These systems are quite reliable and operate over a 30- to 40-mile radius; two to four channel capacity systems start at $500,000. Point-to-point microwave systems operating at 12 gigahertz are employed by a few systems with retransmission installations every 15 to 20 miles along a highly directional beam. At least one university system employs cable television delivery (CATV) off campus, and CATV is a common on-campus technology (Ward, 1974). There is no routine use of satellite transmission at this time in engineering education, though some experiments and planning efforts have been carried out, as is discussed later.

> As long as it is used in the broadcast mode, television is limited to real time reception. When recording techniques were developed and extended to the storage and playback of color images, however, the requirement for simultaneous sending and receiving gave way to the possibility of allowing each function to be performed independently. The addition of time independence to distance viewing has alleviated a major hurdle to the use of television by educators. (Miller and Baldwin, 1975)

The choice of a delivery system without talkback in a given region around a university for minimum cost follows these general guidelines: widely scattered, small class sections tend to favor videotape; small classes concentrated in a geographic radius of 30 to 40 miles tend to favor ITFS, if channel capacity is available; and large installations, over 50 miles distant, tend to favor either point-to-point microwave or videotape depending on frequency of use (Loomis and Brandt, 1973). Yet, there are numerous exceptions in practice, and, as the specific examples cited below illustrate, there are good reasons for these exceptions.

Applications to Engineering Education On Campus

Instructional television on campus may substitute for a live lecturer or provide review and remedial study opportunities. Videotape provides the schedule flexibility needed to support self-paced instruction in the classroom, as well as in laboratory orientation. ITV has several applications in design courses. Finally, students report improved skills in oral presentations and job interviewing techniques when given the opportunity to view videotape replays.

Lectures/Presentations

The use of television on campus often takes the form of lectures and presentations. Some examples will illustrate the wide diversity of on-campus applications.

Regular Classes: Pennsylvania State University pioneered the use of ITV on campus starting in the mid-1950's with CATV to classrooms and dormitories. C. R. Carpenter (1958) reported on these early efforts. Here and elsewhere in the early trials, ITV often was used to present entire lectures in a traditional course. No significant differences in learning were reported initially in these studies. However, the students did gain great flexibility in selecting the time and place for viewing the lectures. Lecture preparation and videotaping took place in a university TV studio; however, production conditions were usually spartan.

In 1971, the Rochester Institute of Technology (RIT) produced a sophomore course in engineering mechanics (Statics) in its TV studios. The 45-minute lectures, the coordinated textbook, and the student workbooks were developed by two RIT faculty in a team teaching approach. The four-credit course employed three ITV lectures a week viewed without proctors from a campus CATV system in small classrooms or dormitories on a very flexible schedule. Cassettes also were filed in the library for individual viewing. The two faculty members met with small groups of students in recitation/problem sessions once a week for two hours as a live supplement to the taped lectures. The performance of the students on examinations was unchanged compared to the previous history of conventional instruction in this course. The department personnel believed the course design and coordinated materials to be superior to those employed prior to 1971. Because the two faculty members were freed from lecturing, they were able to teach more students and to answer questions on a more individual basis than had been the case in the conventional program. Over the four-year experimental period, the costs of initial production plus recitations was lower than the traditional alternative. Nevertheless, the course reverted to a traditional classroom format in 1976 because many sophomores objected to the use of ITV. More than half did not attend the lectures during the last year of the program; rather, they relied on the printed materials and recitiation periods (Kenyon, 1978).

At Colorado State University (CSU), a similar test of ITV for the sophomore core course in electrical engineering drew strong criticism from the students in 1969. However, in this case "the tapes were, at best, plain. There was little use of visuals, there was no rehearsal, there was no director, and there was little effort given to making tapes of professional broadcast quality." (Neidt, 1970) Student performance was assessed, of course, but no control group was maintained for comparison. The course also employed a new, more mathematical approach so that no meaningful comparisons with the performance of students during previous years could be made. In 1970, the course reverted to traditional instruction, using another textbook.

The attitude of undergraduates toward ITV lectures is frequently unenthusiastic despite the fact that learning is not impaired and, in some cases, is enhanced. One of the most sustained efforts on record is the use of ITV for a first year course in accounting at CSU. The objectives stated for this course in 1964 were to:

- Combat the shortage of qualified instructors;
- Bring the instruction of seasoned teachers to large numbers of students through the use of television;
- Standardize the content of elementary accounting courses;
- Provide uniform instruction, testing, and grading;
- Keep classes relatively small;
- Persuade graduate students to become teachers;
- Permit staff members to experiment with new ideas and communication methods; and
- Maintain or improve instructional quality at reduced cost. (McCosh, 1970)

After some experimentation, the course has been refined. Approximately 40 percent of the course now comprises taped lectures that last from 20 to 30 minutes each. The lectures are produced in a studio, and selected portions are redone annually to ensure that the material is up to date. The visual content, e.g., the use of highlights and color for emphasis, is excellent in the current series. Graduate teaching assistants proctor the CATV-delivered lectures in classes of approximately 30 students each; the assistant serves as a tutor for the remainder of each 50-minute period. A printed study guide, which incorporates the lecture visuals, supplements the textbook. For 14 years, this method has been employed for all students in beginning accounting. CSU students who receive this training score well on the norm-referenced Achievement Test, Level I, of the American Institute of Certified Public Accountants.

Over 100 universities, including some of the best, participate in this national examination; the mean grade of CSU students is consistently in the top 25th percentile. Yet, a common student complaint is that "the presentations are somewhat dry and boring."

A survey of 135 departments of accounting in 1973 showed that: 95 had never tried ITV; 15 had tried it but dropped it; and 10 planned to use it but had no previous experience. Only 15 were using ITV, had never abandoned its use, and were planning to continue using it. Some of the impediments cited by the respondents were:

- Students complained that ITV was too impersonal;
- Faculty argued that ITV, as compared to traditional methods, often did not appear to improve learning (the CSU example is contrary to the findings reported in the general literature where no significant difference in outcome is often found);
- Administrators argued lack of facilities and equipment; and
- Faculty incentives were often lacking, e.g., no publication credit for ITV production, and no release time to prepare the ITV lectures. (McCosh, 1978)

This list of impediments illustrates an important feature of ITV in universities today. Well documented courses covering standard material are not generally exchanged among universities. The implicit assumption is that each school will develop its own courses, though most producers presumably could arrange for the lease or sale of materials if requested. Lauer (1978) publishes THE Catalog which lists 550 ITV courses in an effort to stimulate wider use of available materials.

Students react far more favorably when they elect to take an ITV course. Sanford B. Thayer developed 10 half-hour lectures on engineering economy which were studio-produced in color at CSU. A 260-page study guide for the course was prepared to complement a nationally popular text book; it included all of the visuals from the lecture, as well as problem sets with solutions. In 1975, 18 of 72 seniors enrolled on campus chose to take the two-semester course by individual study using the ITV materials. On the three examinations given during the semester, the regular class, which was devoting 30 class hours to the course, scored slightly higher than the ITV students. However, the magnitude of the difference reached the 0.05 level of significance on the second test only. "It would appear the video class learned nearly as much as the regular class. The video class members spent less time on the course than the regular class and also were able to work on it at their convenience. Considering these trade-offs, the videopublished version compares quite favorably with the regular class." (Sjogren, et al., 1976)

From the economic point of view, the ITV picture is bright. With the variety of available approaches to course production and delivery, it is rather easy to present ITV lectures on campus for $1.00 to $3.00 per student-contact-hour (Hayman and Levin, 1973). For the introductory accounting course cited above, the lectures cost about $1.17 per student-contact-hour.

Consider an extreme, hypothetical case. A department could purchase the Thayer engineering economy tapes for $2,485. A videoplayer, color monitor, and cart may cost $1,700. If the department serves only 200 students during the life of this equipment, this coursework (10 half-hour classes) will cost $4.00 per student-contact-hour. (As is customary in higher education, the interest cost of having money invested in capital equipment is neglected in this calculation. If added, the capital equipment base price would increase by approximately 15 percent. Neglecting interest, of course, favors ET over traditional methods.) Very few engineering colleges can teach senior level courses in the traditional way for less than this amount. When more realistic usage of the playback equipment is assumed, the cost of the transmission, delivery, and reception portion of the ITV system quickly becomes negligible. Conservatively, the portable unit described above could cost less than $0.10 per student-contact-hour. In other words, as a first approximation, the cost of ITV on campus can be estimated solely on the amortization of the courseware or cassette. This principle is not new; it has been applied to educational films for years.

An ITV lecture replayed in a classroom may not be the most attractive application of this technology, except from the point of view of reducing costs. ITV has some unique features that permit a variety of interesting applications as the remainder of the examples illustrates.

Lecture Review: The transition from high school to university study is difficult for many students. The failure rate for ethnic minority freshmen in some engineering colleges is alarmingly high. The Massachusetts Institute of Technology (MIT) has employed tutored videotaped instruction (TVI) to address this problem with excellent results. The objectives of the MIT program are: 1) to offer academic support to a selected group of first year minority students in Physics 8.02; 2) to measure the effectiveness of tutored videotape instruction (TVI) as a secondary pedagogical aid; and 3) to determine the transferability to subjects similar to Physics 8.02. Some freshmen were invited to attend both regular lectures and TVI sessions, which lasted two hours each and were held on the same day as the formal lecture. Professor Wesley L. Harris, Sr., reports:

> The concept of instruction of students in the presence of a tutor from videotapes of formal lectures is revolutionary at the very least. From the observation of students immersed in this form of instruction, I feel that this format has great potential. It may actually prove more effective than the traditional lecture/recitation format if given the proper opportunity. From the comments I have heard the students make, the ability to stop a lecture when there is a question in one's mind is far superior to the formal lecture....the personal contact between students and tutor is much more effective than receiving instruction from an impersonal lecturer. In other words, learning from someone you know is much easier than learning from a stranger. (Salloway, 1978)

None of the ten students who participated in TVI received a failing grade, but 25 percent of the minority students who did not participate did receive failing grades.

Videotapes of classroom lectures are used by individual students in a wide variety of settings. The objective often is to provide either a review or remedial opportunities. Direct access to the tapes and playback units may be provided in individual study carrels in the library or in special study areas. Case Western Reserve University, CSU and MIT employ CATV to dormitories to deliver videotaped lectures which supplement lectures in certain core courses. CSU found that only about 25 percent of its freshmen reported using the system, though it is wired into every room. Live tutors at the dormitory in the evening, on the other hand, drew an 80 percent response. Freshmen cited lack of time as a major deterrent. Faculty did not encourage use of the CATV by integrating the taped lectures into the course requirements, nor did they actively discourage its use (Britton and Schweizer, 1974). MIT has some live recitation periods in its campus system with professors answering telephone questions.

Worcester Polytechnic Institute encourages individual study by using ITV in a number of ways. Although a relatively small school, Worcester Polytechnic has 75 to 100 students who use 25 carrels daily to receive supplemental instruction. The videotapes are usually direct and are considered to be almost a visual memoranda by the faculty to students who need additional explanations, data for a problem assignment, or instruction on laboratory procedures (Scott, et al., 1974).

Special ITV classrooms decribed later under off-campus programs operate on about 30 campuses today. Several schools report that campus students are increasingly requesting an opportunity to view tapes made of senior and graduate level lectures. The reasons most often given for the replay requests are to make up missed lectures and to review material.

Summer Session Classes: Summer session presents an annual problem in some engineering colleges due to unpredictable or small enrollments. CSU has resorted to making videotapes in special video-equipped classrooms of several freshmen and sophomore core courses while these are being taught during the regular academic year. The courses are announced in the summer bulletin as programs guaranteed to be offered regardless of enrollment. If enrollments exceed a stated minimum, usually 15 to 20, then the instructor may teach the class in the traditional manner if the class prefers (always) and receive full salary coverage. When the enrollment fails to reach the minimum, the faculty member meets with the class weekly for a two-hour recitation period for half salary and relies on the tapes which he made earlier in the year for the lecture sessions. Students accept this procedure as a good alternative to cancelling courses due to low enrollments. By agreement with the faculty, the tapes are erased at the end of each summer period. The practice of erasing tapes made in the candid classroom mode is universal. On the one hand, faculty do not want the lectures stored for long periods; on the other hand, a very massive tape inventory otherwise would be required.

Classroom Demonstrations: Distance seeing (television) is a unique characteristic that is well suited to instruction in engineering graphics. At Iowa State University, the instructor lectures and demonstrates from a drafting table in direct view of the students. His drafting table has an overhead television camera with controls alongside the table. Each pair of students at a drafting table views an 11-inch TV monitor. In this way, the instructor can face the students while they have a direct, over-the-shoulder view of his illustrations and technique. This drafting room table system has been modified to include a video-cassette player input, making possible the use of modular, studio produced, color instruction by videotape. With this system, instructor time can be devoted to tutorial interactions rather than to presenting lectures (Eide, 1971; 1974). Biology and medical educators have used the unique viewing capability of ITV in a similar manner with great success.

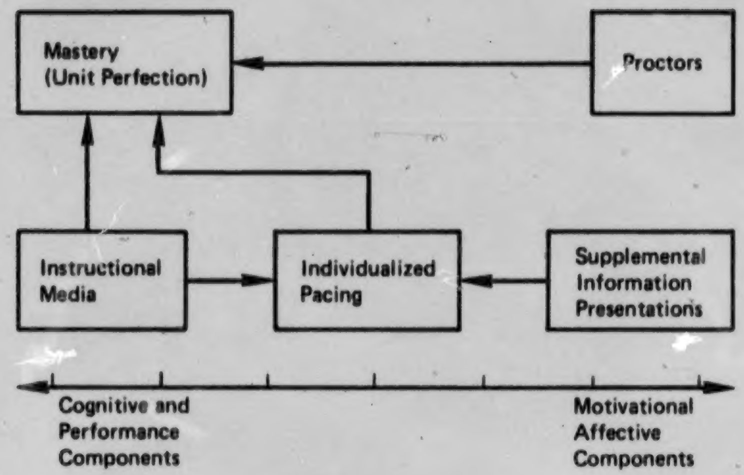
Self-Paced Instruction

Pedagogy which requires self-pacing of study can be mediated using ITV. Perhaps the most popular version is the personalized system of instruction (PSI). The features are:

- The go-at-your-own-pace feature, which permits a student to move through the course at a speed commensurate with his/her ability and other demands upon his/her time;
- The unit-perfection requirement for advance, which lets the student go ahead to new material only after demonstrating mastery of that which preceded;
- The uses of lectures and demonstrations as vehicles of motivation, rather than sources of critical information;
- The related stress upon the written word in teacher-student communication; and, finally,
- The use of proctors, which permits repeated testing, immediate scoring, almost unavoidable tutoring, and a marked enhancement of the personal-social aspect of the educational process. (Stice, ed., 1971)

Figure 2 outlines PSI; each unit forms a set of activities along the lines shown. Traditionally, the instructional media is print. A typical unit contains a reading assignment, study questions, collateral references, study problems, and any necessary introductory and explanatory material.

Role of ITV: Opportunities exist for non-print media, as well (Keller and Koen, 1976). For example, the pre-calculus mathematics course at CSU employs ITV. The decision to use ITV was based on the observation that many students learn mathematical operations by watching a teacher do problems.


Mastery (Unit Perfection)
Proctors
Instructional Media
Individualized Pacing
Supplemental Information Presentations
Cognitive and Performance Components
Motivational Affective Components

SOURCE: Keller and Koen, 1976.

FIGURE 2 Keller's personalized system of instruction (PSI).

An instructional system developed specifically for the pre-calculus program at CSU enrolls more than 5,000 students each fall semester. This system incorporates the mastery-learning, self-paced features of PSI, but avoids the high cost, labor intensity of PSI. Individual examinations, under this system, are scored by a computer rather than by a tutor. Immediate feedback is still provided to the student, however, by printing detailed solutions to the exams in advance and giving them to each student as he/she leaves the testing room.

PSI-like study guides (known locally as "Survival Manuals") are sold through the bookstore. Individual tutoring is available on a walk-in basis throughout the day in the Mathematics Learning Center.

In this system, the content of the usual college pre-calculus has been divided into eight one-credit courses. This arrangement, coupled with a testing program for all entering students, makes it possible to accommodate students entering with different levels of preparation as well as to tailor individual programs for students pursuing non-engineering, as well as engineering majors who are making up deficiencies.

A variety of learning styles as well as learning rates are also provided for by making available several learning resources which students can use in any combination of

> their choice. The resources available include "live" lectures, printed materials, individual tutoring, and now, for the first time, video tapes. The effect of introducing these video tapes remains to be seen, but we are expecting it to reduce the demand for expensive "live" lectures while providing more flexibility of schedule for students learning a self-paced mode. (Brumley, 1978)

The economics of PSI are similar to university ITV in that the cost of courseware preparation dominates. Delivery costs to the university can be relatively small. However, a course which requires the purchase of two or three textbooks is not inexpensive for the college student today.

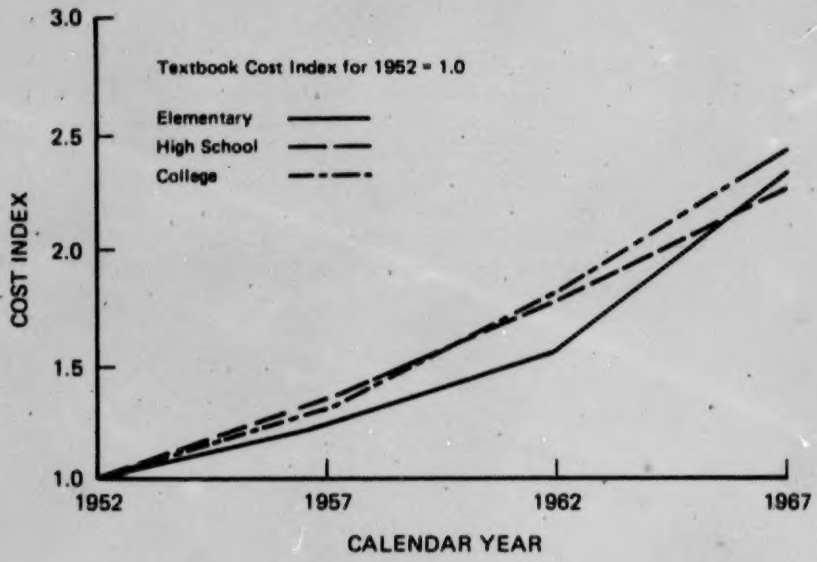
Books as ET: Books are by far the most widely adopted form of educational technology. Traditional instruction and PSI rely heavily on printed material for instruction, and the university has been the classical seat of creation of textbooks. For many years, books have been a consumer product. Calculations of the relative cost of media-based instruction often use as a benchmark cost estimates for traditional instruction which include the cost of the required books. Books are no longer negligible items. In fact, today, the books needed to support 450 contact hours of traditional engineering instruction often cost $150 to $200 per academic year. Of course, the student may lower this by reselling books and/or by purchasing used books. The important point, however, is that apparently all the normal economic advantages of scale have been exhausted in this area. Book costs are showing a steady increase over time as indicated by the data in Figure 3 which were taken from Publishers Weekly and plotted by Hayman and Levin (1973). In considering the economics of all types of ET, the cost of books is a crucial factor.

In Appendix C, the comments of C. G. Bowen (1974) are given. He provides an enjoyable discussion of books as the first educational technology.

Laboratory Courses

Media can be used in laboratory courses in a variety of ways. Students' performance on report writing and presentations can be improved through audio and video recordings. Basic instruction in the use of laboratory equipment can be standardized and streamlined. In addition, the unique capabilities of certain ET's enable close viewing of microscopic experiments as well as simulations of experiments, machinery, and processes that cannot be duplicated on today's campuses.

Report Writing and Presentations: Written reports and oral presentations by students are important parts of many engineering laboratory courses. A number of educators have successfully employed media to improve performance. J. P. Holman (1977) and his colleagues at Southern Methodist University require students to submit a blank audio cassette with each laboratory report. The instructor uses the



SOURCE: Hayman and Levin, 1973.

FIGURE 3 Textbook cost trend.

audio cassette to record comments which are keyed on the student's written report by red penciled numbers and underlined passages. Voice tone adds a fresh dimension to the tutoring. Of even more importance, the relative speed of speaking versus writing makes the task less time consuming and more complete. This is a very effective technique, since virtually all students either own or have easy access to a cassette player.

Several colleges employ video equipped classrooms or portapaks (one-half-inch EIAJ recorders with inexpensive cameras) to record student presentations (Barile, et al., 1977). Some call this microteaching (Perlberg and O'Bryant, 1970). Regardless of the nomenclature, the opportunity to view one's own presentation by replay and to be coached by peers and teachers on needed improvements is valuable. Taken a step further, some students, given the opportunity, become interested in television as an art form and experiment with a wide variety of independent productions through clubs (Salloway, 1978). Just as students who produce the college magazine usually become better writers, students who experiment with readily available and inexpensive TV equipment usually become proficient in the medium. At CSU, the atmospheric science students did the local weather and ski reports on the dormitory CATV. These popular programs included illustrated (graphics and films) mini-lectures on the physical phenomena associated with the weather changes that were predicted to occur.

> Equipment Instruction:
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> Before starting a laboratory experiment in a first year chemistry course at the University of Illinois, Chicago Circle, the entire class will view a color video-cassette that explains the purpose of the experiment and the procedure to be followed, and presents appropriate comments or warnings. These tapes, used for each experiment, are considered an essential part of the laboratory instruction. (Miller and Baldwin, 1975)

The example cited above is representative. Today, many universities are using ITV in many ways to supplement laboratory instruction by providing essential information on the use of laboratory instruments. Unfortunately, these efforts are rarely documented or shared.

Close Viewing: The unique ability of ITV for close viewing is well demonstrated by another laboratory example. Students at Iowa State University learn the electron microscopy of inorganic materials with the aid of a closed circuit television system. The TV camera is mounted where the light binoculars customarily are located, and it is aimed at the fluorescent screen. Demonstrations of the microscope operation are performed for groups of students, rather than for one or two as usually is required. Thus, the instructor is able to maintain contact with each student. Rosauer (1970) gives more details about demonstrations that are particularly effective.

> In another laboratory application, a video camera is used to obtain data from one or more instruments during the progress of an experiment. With several monitors, if necessary, a large class of students can easily see the instruments, take readings at critical points, and use the data so obtained to calculate results from the experiment.
>
> This technique is used at the University of Colorado to allow Civil Engineering students to observe the dials on the large machines that test the strength of materials. The dials are not conveniently located and, normally, would not be visible to more than two or three students at a time. (Miller and Baldwin, 1975)

Simulations: Simulations of laboratory experiments also are possible. One of the most complete and popular set of materials was produced by the National Committee for Fluid Mechanics Films. Largely done in black and white during the 1960's, these films form a rather complete set of illustrated experiments on the fundamental phenomena of fluid motion. A paperback set of notes helps the students and faculty recall and interpret the sound films (Shapiro, et al., 1972). Numerous film loops on single concepts have been edited from the longer films; all materials are distributed by the Encyclopedia Britannica Educational Corporation. To date, this series surely must be the most widely used set of engineering educational films.

The methodology used to produce the series still serves as a model for ITV curricula development today. It involved broadly selected advisory committees, a principal author, and a trained film crew with experienced directors and editors. The work was carried out through the Educational Development Center, Newton, Massachusetts, with funds from the National Science Foundation and, to a lesser extent, the Office of Naval Research. To encourage professional recognition, The Journal of Fluid Mechanics regularly reviews new contributions to this film library.

Many industrial machines and processes cannot be duplicated on campus. Nonetheless, educators may wish to expose students to certain aspects of current practice. Field trips to neighboring firms may help, but the local selection usually is narrowly limited. Films produced by educators through an organization patterned after the one described above could greatly enlarge such instructional opportunities. The films could involve not only industrial operations but also national government laboratories. Of course, it is essential that clearly stated instructional objectives be identified and that the TV or film production be directed by professionals.

Design: Project Courses

The senior design course is viewed by many educators as the capstone of the undergraduate experience. At least three approaches are employed: project courses (authentic involvement); case studies; and guided design. Koen (1976) discusses each method briefly and gives primary citations in the literature. ITV does not yet play a central role in any of these instructional techniques, but examples can be cited to show its potential.

Project courses are the most common design experience of students. Students learn the art of design by designing. A good insight into the various practices employed across the country is provided by the Proceedings of the Conference on Engineering Design Education entitled "Authentic Involvement in Interdisciplinary Design." (Bulkeley, ed., 1965)

Projects play a central role in the innovative undergraduate program at Worcester Polytechnic Institute. A self-paced, individualized approach is taken in the project activity with the extensive support of do-it-yourself videotapes. For example, the Projects Instrumentation and Measurements Experimental Learning Laboratory consists of a series of mediated modules specifically designed to support students in project activity. The lab is open to students of all disciplines who come to obtain information, and, ultimately, select the method and instruments consistent with their project goal (Scott, 1978).

In some projects which have a high visual content, ITV can become an integral part of the student work. For example, faculty and students of the Department of Urban Studies and Planning at MIT prepared a 16-minute videotape documentary on "Copley Square," a planned development of shopping facilities, convention hotel, and parking (Salloway, 1978). The documentary examined a controversy surrounding a demand issued by community groups that the developer, a Chicago firm, build low-income housing as part of their Copley Square Air Rights proposal. Salloway reports that "video brought unique capabilities to the group discussion process such as compression of time events, the ability to allow viewers to witness interactions and present relationships they were not likely to see." The use of the tapes by people involved in the actual events led the MIT staff to conclude that "telecommunications can reverse the 'trickle down' relationship in which citizens are on the receiving end of public policy outcomes. Visual productions like 'Copley Square' have the power to shape public debate and to create a platform for public consensus." Once completed, the taped report was filed in the Laboratory of Architecture and Planning for later use by students.

Design: Case Studies

Case study is common in business and law education. Since 1964, a growing group of engineering educators has worked to make the case studies method a valuable part of engineering instruction (e.g., Vesper and Adams, 1969; 1971). Today, the headquarters of the American Society for Engineering Education (ASEE) publishes an annual catalog containing about 270 documented and reviewed cases which are available for a nominal charge. About 100 orders are filled annually. A total of 988 individual cases were distributed last year; the most popular dozen cases were requested 10 to 14 times. Almost without exception, the cases are typed manuscripts which are reproduced on demand. Though protected by copyright, permission to copy cases locally is routinely given.

Role of ITV: In a quite separate activity, the Open University of the United Kingdom has demonstrated how TV can add an important dimension to case studies. The Open University prepares coordinated sets of materials built primarily around a paperback textbook, but these are supplemented by both audiotapes and videotapes. Two excellent examples (from a rather short list of interest to engineers) are the courses on "Systems Performance: Human Factors and Systems" and "Systems Modelling." Case studies, produced by the British Broadcasting Company (BBC) on audiotapes and videotapes, are interspersed throughout the course. Note that not only do the cases provide motivating interludes to consolidate learning, they also offer specific examples of both the applications and the limitations of theory.

ITV offers the instructor an important complementary tool in the case study approach to engineering education, but the resources required if ITV is to have a significant impact are not yet available. Indeed, the Open University material appears to be the only available in engineering education to date.

Professional Ethics: Instruction in professional ethics for engineers is being encouraged anew. The U.S. accreditation society, Engineer's Council for Professional Development/Accreditation Board for Engineering and Technology (ECPD/ABET), devoted much of its 1977 Annual Meeting to this topic. Team teaching approaches, which usually involve philosophy and engineering instructors, are gaining favor. Much, much more needs to be done in this area; it has been neglected for a decade.

One powerful example from medical education is cited to illustrate the potential of media in instruction in professional ethics. "Who Should Survive" is a 26-minute film from the Joseph P. Kennedy, Jr. Foundation (Film Service, 999 Asylum Avenue, Hartford, Connecticut). The case described is an adaptation of an actual case that occurred at the Johns Hopkins Hospital; the staff play their real life roles. A mongoloid child is born with an intestinal block which can be cured only by an operation. The parents do not want the burden of a retarded child and refuse to permit the operation. The surgeon and hospital do not challenge the decision in the courts. In 15 days, the infant dies. A panel of five persons (a mother, a physician, a priest, a law professor, and a sociology professor) discusses the ethical, legal, and scientific issues involved. The viewer is left with a set of provocative questions. Did this helpless infant have to die? Did the doctors and the hospital have to accede to the parents' refusal to permit a simple operation? Was there no appeal to higher authority? Who decides who should survive? The film is acclaimed as an outstanding instructional tool. A brief printed enclosure is provided to help stimulate and guide discussion; it also provides a list of suggested readings.

Engineers also face ethical dilemmas in complex situations that often involve human safety and well-being. Production of films presenting case studies similar to the one described above would be an excellent project for foundations to underwrite. The American Bar Association has a modest effort underway for lawyers (Hamblin, 1978). Although no comparable films exist on ethical issues in engineering practice, The American Society for Civil Engineers has begun circulating to student chapters an hour-and-a-half videotape which focuses on the procedures that society follows in reaching decisions on ethical complaints. Also, a clearinghouse for materials, such as course outlines and reading lists, has been established at Rensselaer Polytechnic Institute for instructors in professional ethics for engineers. In addition, the National Science Foundation's Science Education Directorate sponsors a very modest set of projects that are primarily aimed at documentation.

Interviews/Career Guidance

Engineering education usually neglects the rich human history of the profession. Young people today show more interest than their recent predecessors in the values and personalities of engineers in practice. Florman's book, The Existential Pleasures of Engineering (1975), is a reflection of this concern. Television might play a unique role in bringing life to a curriculum overburdened with abstract analysis.

The Bell Laboratories are now producing a documentary television series which they call "Communications Milestones." These are brief, informal visits with engineers and scientists who have made outstanding contributions. They describe the setting for their discovery, the work which led to the concept or invention, and the reaction of their peers and the profession in the United States and abroad. One of the most interesting features in each tape is the insight provided by the individual inventor about his own experience with the creative process (Feinstein, 1978).

Business educators have created a clearinghouse to encourage the development and distribution of video documentaries with the support of a private foundation. The objective is to videotape interviews with contemporary business leaders in their areas of expertise. The material has many uses. For example, a workshop for educators was held in 1977 at CSU where the files are maintained.

Ellison Smith (1974) discusses the use of TV and radio to assist engineering colleges in influencing high school students in making career decisions. Examples range from radio spots with popular disc jockeys to films aimed at minorities and women.

John Truxal and Ludwig Braun created the National Coordinating Center for Curriculum Development at SUNY-Stony Brook to increase the number of minority students who chose to study engineering. Working with young people in grades 9 through 12, they provide resource material to schools in Chicago, New York City, Atlanta, Rochester, Buffalo, and California (MESA Program). Films prepared by industry to interest minority students in engineering careers are proving to be effective motivational resources. The use of calculators and personal computers as a part of this program is described later in this report.

The most popular films shown on the freshman dormitory CATV at CSU deal with career guidance. Many freshmen are uncertain about a specific major and the variety of work available upon graduation. Unfortunately, many of the films available from government agencies and technical societies are heroic rather than realistic in portraying the work of engineers. The ASEE Annual Meeting usually sponsors a "film fair" where these materials may be viewed and discussed.

Applications to Engineering Education Off Campus

Off-campus applications clearly surpass all other uses of ITV in engineering education. Since the mid-1960's, over 30 major colleges of engineering have developed regional ITV systems to deliver both graduate and continuing education to engineers at their job sites. Recently, 22 of these universities have formed a consortium to extend these services nationwide. Other examples of ITV used to link colleges of engineering with junior colleges, high schools, and foreign universities show considerable promise but are rare.

Graduate Education

The Goals of Engineering Education report in 1968 (Pettit and Hawkins, 1968) recognized the need for developing "on-campus study programs for employees of nearby industry and government laboratories," as well as for continued experimentation in "extending high quality advanced-degree education to engineering students employed at locations remote from established campuses." This recommendation has been widely supported in the engineering academic community, and it has been implemented primarily through the use of ITV systems. Early experiments with leased microwave links for an occasional class have evolved into large operational programs using a variety of dedicated delivery systems throughout the year.

Table 1 lists the academic credit video-based engineering graduate programs by originating university and provides the following information: program starting date; delivery method; number of remote locations served; number of engineering courses; total enrollments off campus; and an indication of whether graduate business courses are offered in conjunction with engineering courses in the delivery system. These data were collected specifically for this paper; any omissions should be reported to the authors.

The graduate courses are regularly scheduled on-campus offerings which are attended by full-time students. The classes are held in specially equipped studio classrooms so that not only the lectures but also the student questions and discussions are transmitted. To convert a regular classroom for video origination, together with the usual control equipment, costs from $25,000 to $35,000 (Miller and Baldwin, 1975).

Although the studio-classrooms are similar, a variety of signal delivery systems are employed to link the graduate students at job sites to the campus. The first major system, established in 1964 at the University of Florida, employed two-way, point-to-point microwave which was leased from the telephone company to link the main campus to several extension centers in central Florida. In 1969, Stanford University began serving in-plant classrooms in the San Francisco Bay Area with a four-channel instructional television fixed service (ITFS) system that featured FM-talkback capability. In 1967, CSU was the first to employ courier-carried videotape as a delivery system; tapes are returned, erased, and reused on a schedule. Today, most microwave and ITFS receiving sites are equipped with video recorders to store the instruction temporarily either for review or for making up missed classes. By scheduling occasional visits and regular office hours for telephone consultations, faculty employing videotape in regional systems have largely overcome the talkback disadvantage of videotape delivery. The convenience of decoupling the campus and part-time student schedules is, of course, a major advantage of videotape. Newer systems tend to employ combinations of delivery methods to fit the needs of specific geographic areas.

A study of the ITV operations at Stanford, University of California at Davis, and CSU showed that the dominant cost in all three systems is administrative program management and technical manpower to run the

TABLE 1
ACADEMIC CREDIT
ENGINEERING GRADUATE PROGRAMS OFFERED OFF CAMPUS BY TELEVISION
1979-80

Program (Starting Date)	Delivery Method	Remote Locations	Total Courses	Total Enrollments	Graduate Business Courses Also
University of Rhode Island (1961)	Microwave		Discontinued 1979		No
University of Florida (1964)	Leased Microwave		Program Ended in 1972		
Southern Methodist University-TAGER (1967)	Microwave + ITFS + Videotape	16	75	1152	No
Colorado State University (1967)	Videotape	37	76	900	Yes
University of Tennessee (1967)	Videotape	16	55	568	Ceased 80-81
University of Illinois/Urbana (1967)	Blackboard by Wire	4	22	140	No
University of Colorado (1968)	Videotape + ITFS	14	15	152	No
Stanford University (1969)	ITFS + Videotape	45	149	2373	No
ACE at Stanford (1969)	ITFS + Videotape	36	10	448	Yes
Iowa State University (1969)	Videotape	15	34	275	Yes
University of South Carolina (1969)	ITV + Videotape	33	51	2385	Yes
MIT (1969)	Videotape		Only Non-Credit Courses Offered		
University of Kentucky (1969)	Film + Videotape		Only Non-Credit Courses Offered		
University of Michigan (1970)	Leased Microwave + ITFS	11	46	311	Yes
University of California at Davis (1970)	Microwave + Videotape	3	47	320	No
Purdue University (1970)	Microwave + Videotape	15	12	166	No
University of Wisconsin (1970)	ETV+Videotape+Electrowriter+Telephone Network	NA	NA	7	No
University of Minnesota (1971)	Microwave + ITFS + Videotape	17	55	909	No
Rochester Institute of Technology (1971)	Videotape				No
Oklahoma State System (1972)	Microwave & ITFS	NA	NA	NA	Yes
University of Maine (1972)	Live Video, Audio Return		Not Currently Operating		
Case Western Reserve (1972)	Videotape	50	41	326	Yes
University of Southern California (1972)	ITFS	27	92	785	No
University of Arizona (1972)	Videotape + Microwave(Out) + Slow Scan (Return)	20	47	97	Yes
University of Pennsylvania (1972)	ITFS		Not Currently Operating		
Cornell University (1973)	Videotape				
University of California/Santa Barbara (1974)	Microwave + Videotape	2	23	95	No
University of California/Berkeley (1974)	Microwave + Videotape	6	30	-	No
University of Idaho (1975)	Videotape	130	32	332	Yes
University of Massachusetts (1975)	Videotape	128	26	154	No
Illinois Institute of Technology (1976)	ITFS	18	114	780	Yes
North Carolina State University (1976)	Videotape	12	14	220	No
Georgia Institute of Technology (1978)	Videotape	10	18	105	Yes
Polytechnic Institute of New York (1978)	Videotape				
Worcester Polytechnic Institute	Videotape - In Planning				
University of Maryland	Beginning 1980-81				Yes
Auburn University	In Planning				

video technology (Loomis and Brandt, 1973). This factor accounts for $20 to $30 of a "total" cost of $30 to $50 per TV classroom-lecture-hour. Furthermore, another $4 to $7 per TV classroom-lecture-hour is required to outfit the TV classroom regardless of delivery mode. Audio talkback, if used, is surprisingly expensive, perhaps $1 to $7 per TV classroom-lecture-hour. In the total cost cited above, no provision to pay the instructor is included, the argument being that the instructor is simply adding off-campus students to a regularly scheduled class. Even with this drastic assumption of cost allocation, only one university (Stanford) has demonstrated full recovery of the incremental costs of its television delivery system (Morris, et al., 1974). It is important to note, however, that virtually all tuition and other direct charges are paid by the employer in every system.

It should be no surprise that regular campus classes appeal primarily to the young engineering employees. Several universities listed in Table 1 report that only 5 to 15 percent of the off-campus course enrollees for credit are engineers over 35 years of age (Schmaling, 1974). Often, about a third of the participants in these credit programs are pursuing a program of study leading to a M.S. degree. The cumulative degrees awarded to date to ITV students at their job sites is summarized in Table 2.

Federal government grants were not a significant factor in the development of any of the systems listed in Table 1. User subscriptions to a capital fund, private foundation donations, and state and university funds built the systems. The engineering outreach programs are a local, grassroots response to a professional need.

The ITV programs are very effective and popular with the mature, goal-oriented engineers who elect to participate. Convenience is often cited as motivating factor: "time saved in travel to class"; "only way available"; "can make up classes missed while on business travel"; "fits my work schedule" (Neidt and Baldwin, 1970; Stutzman and Grigsby, 1973; Down, 1976). The average performance of off-campus students is usually quite close to that of the on-campus students when comparable admission criteria are employed. R. M. Anderson, Jr. reports on evaluations of 1,500 students enrolled in 60 ITV courses at Purdue University using a variety of delivery modes both on and off campus:

> The data indicate that students do learn by televised instruction, that students prefer TV-with-audio-talkback over videotaped instruction, and that students prefer live instruction to either kind of televised instruction. (Anderson, 1978)

The results above pool both on-campus and off-campus student attitudes.

Rogers (1978) compares the broadcast mode with videotape delivery based on the experience at Case Western Reserve University. He concludes:

> While each case must be decided on its own merits, our member companies have opted for videotape, largely on the basis of its scheduling convenience and flexibility. (Rogers, 1978)

TABLE 2

GRADUATE PROGRAMS OFFERED OFF CAMPUS BY TELEVISION

MS Engineering/MBA Degrees Awarded to Date

University of Rhode Island	NA
University of Florida	253
Southern Methodist University-TAGER	331
Colorado State University	165
University of Tennessee	114
University of Illinois/Urbana	NA
University of Colorado	2
Stanford University	245
ACE at Stanford	170
Iowa State University	10
University of South Carolina	375
University of Michigan	160
University of California at Davis	50
Purdue University	183
University of California/Santa Barbara	82
University of Minnesota	55
Oklahoma State System	NA
Rochester Institute of Technology	51
Case Western Reserve University	40
University of Southern California	525
University of Arizona	11
Cornell University	4
University of Idaho	10
University of Massachusetts	1

(11/80)

Gibbons, et al. (1977) report on the use of videotaped instruction which is supported by local tutors drawn from the engineering staff of the industrial sponsor. Data are presented that show that the part-time students in industry can significantly out-perform campus students with comparable academic records in the same course.

Very little systematic research has been undertaken to determine the relative importance of various courseware and environmental variables in the video-based instruction of adult professionals. The operating systems are large enough and sufficiently dispersed to enable statistical studies to be designed, but external funds and specialists not now involved in these operations are necessary to undertake such work. Moreover, the operating systems themselves could not support such studies from existing revenues.

The ITV invasion of the job site has benefited not only the participating students, but it also has benefited the engineering faculty who find regular interaction with the industrial students stimulating and professionally rewarding. Figure 4 shows the steady growth of these off-campus graduate and continuing education programs nationally. The enrollment data provided include the non-credit, continuing education application of ITV as discussed in the next section. Non-credit offerings are currently the most rapidly growing segment of off-campus ITV in engineering education.

A number of unresolved problems are worth noting however. Most of the programs are regional and employ a courier to carry hardcopy to and from campus. An important element in the increased productivity of faculty in these programs is the ability to keep all student groups on a reasonably close schedule. Otherwise, a faculty member actually teaches many different courses rather than different sections of the same course. At long distances, say over 100 miles, maintaining a schedule can be very difficult, though both the University of Arizona and Stanford University have experimented with videotaped credit courses at distant sites. New communications technologies promise to help overcome the regionalism which dominates these systems today.

Continuing Education

A relatively stable population of engineers is increasingly involved with the development of new technologies and with changing societal attitudes toward technology. Recent studies (e.g., Alden, 1974 and Seltzer, 1975, 1976) place the engineering workforce at over a million people. Nearly all of these are men and many are without college degrees in engineering. One of the difficulties in coping with change is the relatively slow growth of the profession. The median age is 43, and the rate of entry of new graduates into the field of engineering today barely exceeds the rate of departure through death, retirement, or change of occupation. Concern arising from charges of age-discriminatory practices has prompted the enlargement of continuing education opportunities in some firms and agencies (e.g., Rivers, 1975 and C&E News, 1975).

Participants in continuing education courses usually differ in age and motivation from part-time graduate students. Academic credit is much less important, though some recognition or certification is often desired. Professional development *per se* is often cited as a dominant motivation: "keeping up to date"; "useful in job"; "self-improvement"; "learning new skills." Down (1976) reports that auditors in the Stanford ITV system have an average age of 38.1 years, compared with 27.9 for the engineers who take the courses for credit.

In addition to allowing auditors in regular graduate classes, special curricula are developed to serve the continuing education needs of engineers in the Stanford system by the Association for Continuing Education (ACE). This non-profit organization is a unique regional consortium of universities and employers of engineers (Davis and Gunderson, 1974). It also uses the Stanford ITFS delivery system. A wide variety of courses is offered by ACE. Instructors drawn from industry rarely teach these courses, though this was part of the

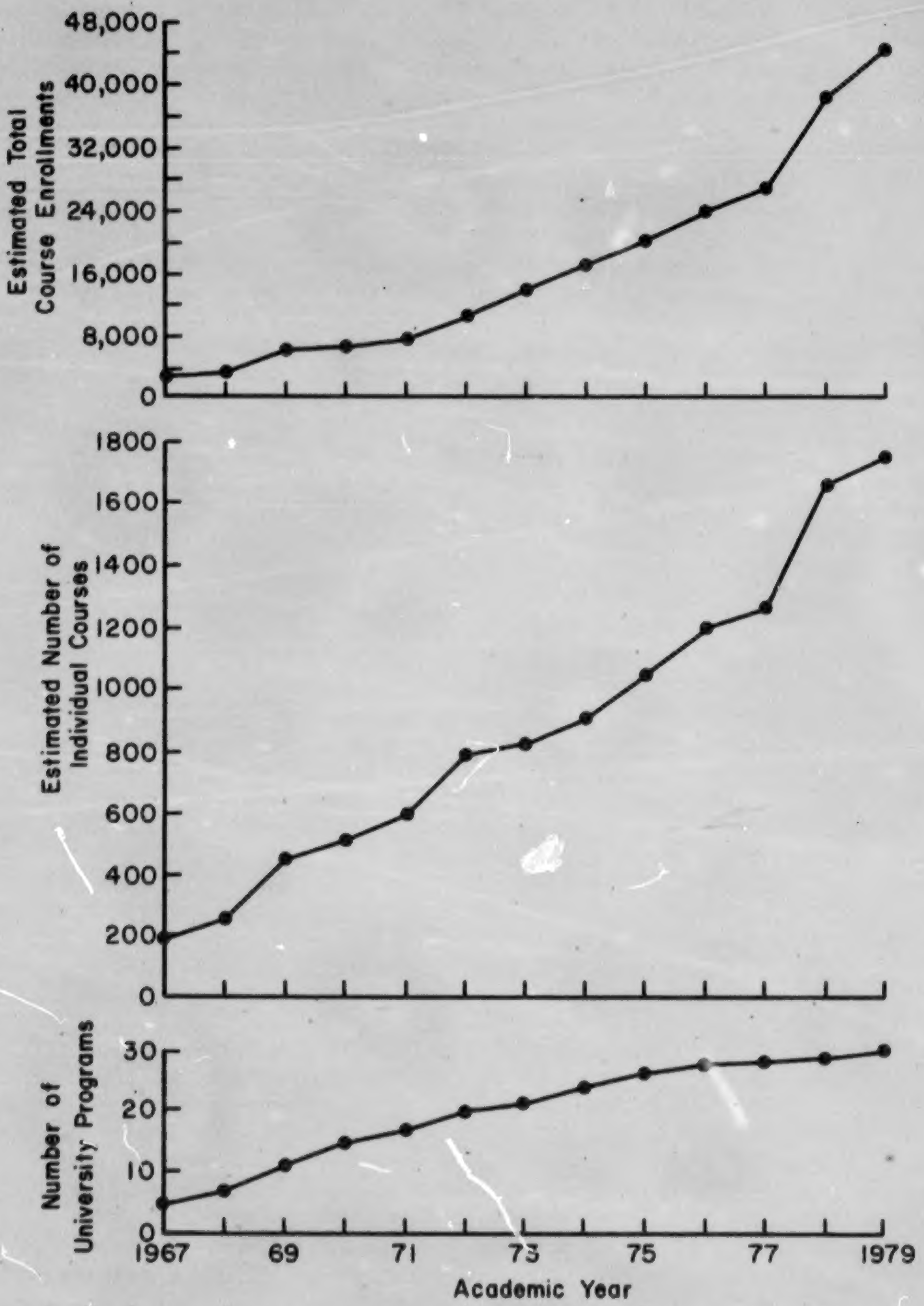


FIGURE 4 Engineering graduate and continuing education programs offered off campus by television.

original rationale for forming ACE. The continuing education offerings generally are scheduled after regular working hours, and, apparently, some companies have enough red tape to discourage potential instructors. ACE courses usually are taught in the candid classroom mode during hours when Stanford does not schedule other programming, e.g., early morning, noon, late afternoon, and evening.

The Center for Advanced Engineering Study (CAES) at MIT pioneered the development of continuing education packages. These modular courses consist of a coordinated set of videotaped lectures/ demonstrations, study guides that include all of the visual aids used in the lectures, problem sets with solutions, textbooks, and, occasionally, computer decks and manuals. The average length of a course is 12 to 15 lectures, each about 30 minutes long. The content is oriented to practicing engineers, not young graduate students. The videotapes are produced in a color studio with the benefit of special graphics and highlighting techniques. The materials so produced are available at any time of the year, since, unlike the classroom tapes described earlier, the intention here is to create a master tape for later reproduction or videopublishing. Distribution is an expensive, frustrating feature of videopublishing today. Indeed, MIT-CAES was not able to meet expenses during any year from the inception of the program to 1975. This program has continued to grow steadily, become self-supporting, and now is the largest effort of its kind in the world.

Perhaps this explains why only a few universities have produced more than one subject in this packaged format. The University of Wisconsin Extension has four video-based courses in engineering with specially designed textual materials. Rochester Institute of Technology has produced 10 courses in a studio for national distribution. ACE has developed several topics, and CSU has 22 short courses which were prepared in its color studio. Overall though, videopublishing for engineering continuing education in campus studios is in its infancy.

Other non-university organizations have produced video-based courseware for the use of practicing engineers. Commercially, the most notable are: Advanced Systems, Inc., which lists over 50 multi-media courses, varying from three to ten video sessions each, in management and electronic data processing; Texas Instruments, which lists over 10 multi-media courses of about 10 sessions each on solid state electronic technology; and Hewlett Packard, which lists over 160 topics in electronics and in the operation and maintenance of a wide range of specific equipment. Many other firms have employed video-based instruction for in-service training, and companies such as IBM and Bell Telephone Laboratories have modest catalogs covering a variety of subject matter. However, with the exception of the Advanced Systems, Texas Instruments, and Hewlett Packard courseware, there is little sharing of such materials across company lines.

The activities of technical societies in media-based continuing education for professionals was the subject of a conference in 1977 (Lykos, 1978a). The American Chemical Society (ACS) reported on the use of 5 ACS videotaped short courses and 37 audiotaped short courses, all with coordinated printed material. The ACS is currently engaged in an evaluation of individually controlled, media-augmented courses with the assistance of a $830,000 grant from NSF. This is slated for completion in 1981. The Society of Manufacturing Engineers reported on the development of a number of short courses and single-topic lectures for videotaped distribution. A representative of the American Medical Association discussed work underway to use a microprocessor controlled videodisc. However, most technical societies presented a very cautious approach to media, viewing ET as a costly and risky venture for self-supporting, continuing education groups to undertake.

At MIT, Project PROCEED (Program for Continuing Engineering Education) is relying primarily on printed material arranged in modular fashion for individual study. The design features include effective use of case studies as well as an elaborate adaptive reference system. Preliminary reports on this $770,000 effort, the only other large NSF activity in continuing education, are available (Cohen, 1977, 1978).

In an earlier development, representatives from all of the colleges of engineering known to have ITV systems in operation gathered in Dallas for a "Workshop on Continuing Education for Engineers at Midcareer" in August 1974. The 70 participants were drawn equally from industry and universities. Features of in-plant, video-based instruction which were viewed favorably in the discussions were summarized as follows:

> Participants from both industry and universities discussed the potential advantages of videotaped instruction which are not yet widely exploited in existing programs. For example, distribution can potentially be nationwide to spread the cost of curricula development and delivery over many learners. Files can be maintained at the discretion of the user. The "best" instructors can be contacted in a region or discipline area. Evaluation can lead to revision and improvement of specific segments of an instructional program. Live instructors drawn from the universities or student peer groups can adapt and supplement the video modules in much the same fashion that many university instructors now employ textbooks, at reasonable additional cost. Intensive short courses and longer study leaves are, of course, very effective continuing educational activities, but, because of the time away from the job, only a small percentage of the engineers have an opportunity to participate. Indeed, the rarity makes it something of a reward for good service in some firms or a transition signal of a promotion. Video instruction in the place of employment at a reasonable cost offers the real potential of serving many engineers. (Baldwin, et al., 1974)

Some of the shortcomings of these early efforts were also listed:

> Among the factors which were identified as contributing to this poor result are: university courses are graduate offerings in engineering which require more skill in

> mathematics than the older engineer possesses; fear of competition for grades with younger engineers; lack of relevance of coursework to job; job related incentives are lacking and indeed may actively work against the older engineer seeking credit or a degree from a university; family pressures which compete with study time off the job. Coursework has not been designed which correlates well with the professional growth of engineers, either as technical specialists or as managers. Some participants felt strongly that up-dating of technical skills had been over-emphasized (who wants to admit that he is outdated?), and that even MBA programs, where available, are not well designed for engineers seeking management positions. (ibid.)

Tribus (1975) argues that more attention must be paid in continuing education to the way industry usually organizes engineering work into specific functions such as designing, manufacturing, and evaluating. These activities draw on a variety of traditional engineering disciplines in ways which are often unique to an industry.

A number of planning sessions followed the 1974 Dallas workshop in which sets of mutual objectives were identified and an organizational structure formulated. In April 1976, twelve university representatives formally created a non-profit corporation called the Association for Media-Based Continuing Education for Engineers (AMCEE). This consortium of universities that operates ITV systems sets out its goal: To increase the national effectiveness of continuing education of engineers. The member institutions today are:

TABLE 3
AMCEE MEMBER INSTITUTIONS

Auburn University
Case Western Reserve University
Colorado State University
Georgia Institute of Technology

Illinois Institute of Technology
Massachusetts Institute of Tech.
North Carolina State University
Polytechnic Institute of New York
Purdue University
Southern Methodist University
Stanford University

University of Arizona
University of California/Davis
University of Idaho
University of Illinois, Urbana-Champaign
University of Kentucky
University of Maryland
University of Massachusetts/Amherst
University of Michigan
University of Minnesota
University of South Carolina
University of Southern California

> Before AMCEE, these schools were independently offering television-based courses at the graduate level to on-the-job engineers at their place of work but were drawing only on their separate faculties to develop and teach such courses. This was a wasteful non-system of

> providing for a homogeneous group of people with a real need for, and a strong interest in, advanced education, and it prevented the offering of specialized courses for which there was a demand but no expertise in the local faculty.
>
> The obvious solution was some kind of cooperative organization that could sponsor the development of courses and other materials for use by all the schools involved, that could share development costs among the schools, and that could afford to offer highly specialized courses that might have only a few students at a given site but a substantial number throughout the consortium. AMCEE expects its membership to grow to twenty-five or more institutions in the next few years and expects to expand its offerings to laboratory technicians and other people besides engineers working in technical jobs. AMCEE uses a revolving fund from which awards are made on a competitive basis for the development of new courses, and this venture capital will be returned to the fund as new courses are brought by the members of the consortium and by other institutions. Whether a similar consortium might be appropriate in other large professional fields such as medicine, nursing, law, management, and public school teaching is a question that should now be explored. (Koerner, 1977)

The Sloan Foundation and NSF have provided funds to launch a coordinated set of activities which addresses both the goal of the organization and the long-term need for AMCEE to be self-sufficient by virtue of the sale of its services. AMCEE produced a catalog of 172 courses from 10 universities in July 1978; the October edition listed 224 courses from 15 universities. The 1979/80 AMCEE catalog listed over 350 courses from 15 universities; by 1980/81, over 450 courses from 21 universities appeared. For the first time, university ITV courses are available from a single source nationwide.

Several special workshops and seminars on timely topics of interest to engineers have been held; each drew on talent from several colleges for faculty. A biannual directory of all continuing education opportunities for engineers plus a telephone information service supported by a word processor are scheduled for introduction in late 1980. AMCEE sponsored the conference cited earlier (Lykos, 1978a) at the United Engineering Center, New York City, September 28-29, 1978. This meeting brought together representatives of many major technical societies and universities to discuss ways to cooperate in the use of media in continuing education. AMCEE also sponsored a feasibility study on the possible use of modern communications technology and satellites as discussed in Chapter III.

Videopublishing received a boost three years ago when the University of Southern California (USC) started its Employee Development Program. Courses produced at other institutions are previewed on the USC ITV system periodically. Those drawing sufficient response are scheduled for distribution over the system on a non-credit basis. Enrollments in these non-credit courses now exceeds that of the regular credit offerings. AMCEE has encouraged similar successful programs at the University of South Carolina, the University of Michigan, Purdue, and CSU.

An evaluation of the CSU program showed that the off-campus students were not concerned about where the course was prepared. Rather, they focused on the relevance and quality of the instruction (Sjogren, 1976). Table 4 summarizes the non-credit program enrollment for 1979-80. The regional ITV systems promise to be effective distributers in the videopublishing field. In addition, the regional ITV systems often supply the advising, tutoring, and quality control functions needed by the industrial subscribers. As previously noted, these non-credit programs are the most rapidly growing segment of ITV instruction.

Evaluations of continuing education programs are customarily limited to attitude surveys of the participants. Employers usually express faith in the long-term benefits and do not fret over evaluations (Sanders, 1974). Morris (1978) reports on an NSF-sponsored study which attempts to measure the return on investment in continuing education of engineers. Detailed data on approximately 400 individuals in three firms and a government research laboratory were coded for 5 to 15 years of employment records. In addition to continuing education participation, other characteristics of the individual were coded such as quality of performance on the job, college stature and college grade point average, honors, and personal drive. Morris reports "a convincing statistical association between continuing education and performance, and a demonstration that it is not a false association created by any other variable which was measured." In a less ambitious study, Klus and Jones (1975) reported that "participation in continuing education programs (in this case, short, live courses) seems to have a positive effect on those job factors pertaining to salary and satisfaction with present job status."

Some of the current impediments to the use of ITV at the job site for continuing education include:

- Lack of a well-accepted credentialing method (the CEU or continuing education unit draws mixed responses);
- Lack of curriculum depth; and
- Inefficient distribution economics for materials designed for continuing education.

Junior Colleges

Resource sharing is particularly attractive when budgets are lean in higher education. The rapid expansion of junior colleges during the late 1960's left many state university systems with tight budgets. Many junior colleges were poorly funded from the outset, yet colleges of engineering increasingly are asked to assimilate transfer students

TABLE 4
NON-ACADEMIC CREDIT
ENGINEERING CONTINUING EDUCATION PROGRAMS OFFERED OFF CAMPUS BY TELEVISION
1979-80

Program (Starting Date)	Delivery Method	Remote Locations	Total Courses	Total Enrollments
University of Rhode Island (1961)	Microwave		Program Discontinued 1979	
University of Florida (1964)	Leased Microwave		Program Discontinued 1972	
Southern Methodist University-TAGER (1967)	Microwave + ITFS + Videotape	16	75	60
Colorado State University (1967)	Videotape	525	24	2934
University of Tennessee (1967)	Videotape		All Credit Courses Offered	
University of Illinois/Urbana (1967)	Blackboard by Wire	4	22	16
University of Colorado (1968)	Videotape + ITFS	11	5	121
Stanford University (1969)	ITFS + Videotape	45	149	1655
ACE at Stanford (1969)	ITFS + Videotape	36	68	3615
Iowa State University (1969)	Videotape	NA	1	826
University of South Carolina (1969)	ITV + Videotape		All Credit Courses Offered	
MIT (1969)	Videotape	800	24	15,000
University of Kentucky (1969)	Film + Videotape	29	2	910
University of Michigan (1970)	Leased Microwave + ITFS	11	46	352
University of California at Davis (1970)	Microwave + Videotape	3	47	103
Purdue University (1970)	Microwave + Videotape	13	17	688
North Carolina State University (1970)	ETV + Videotape	30	11	706
University of Wisconsin (1970)	ETV+Videotape+Electrowriter+Telephone Network	NA	30	1289
University of Minnesota (1971)	Microwave + ITFS + Videotape		All Credit Courses Offered	
Rochester Institute of Technology (1971)	Videotape			
Oklahoma State System (1972)	Microwave + ITFS		All Credit Courses Offered	
University of Maine (1972)	Live Video, Audio Return		Not Currently Operating	
Case Western Reserve (1972)	Videotape	50	41	14
University of Southern California (1972)	ITFS	27	153	2798
University of Arizona (1972)	Videotape + Microwave(Out) + Slow Scan (Return)	60	44	NA
University of Pennsylvania (1972)	ITFS		Not Currently Operating	
Cornell University (1973)	Videotape			
University of California/Santa Barbara (1974)	Microwave + Videotape		All Credit Courses Offered	
University of California/Berkeley (1974)	Microwave + Videotape	6	30	250
University of Idaho (1975)	Videotape	20	8	209
University of Massachusetts (1975)	Videotape	8	7	175
Illinois Institute of Technology (1976)	ITFS	7	7	114
Georgia Institute of Technology (1978)	Videotape		All Credit Courses Offered	
Polytechnic Institute of New York (1978)	Videotape			
Worcester Polytechnic Institute	Videotape - In Planning			
University of Maryland	Beginning 1980-81			
Auburn University	In Planning			

who have two years of study in junior colleges. Project Co-Tie, which began in 1968, seeks to achieve increased and enhanced educational opportunities by means of resource sharing among Colorado junior colleges and CSU.

> Since its beginning Co-Tie has included, among its activities, the offering of pre-engineering courses to participating colleges. Electrical Circuits, Statics, Dynamics, Fluids, and Thermal Sciences are common core pre-engineering courses which have been videotaped for use in the program. Six of the participating colleges offered two-year pre-engineering programs; however, each of the programs had notable differences primarily in the sophomore engineering courses. The Co-Tie project supplemented each of the pre-engineering programs to the extent that a student could transfer into a four-year program as a full-fledged junior. The videotaped courses are made available free of charge to the colleges to use in a manner dictated by local faculty. Each of the colleges charges its own tuition and awards its own credit for the courses even though the material is identical to that offered at Colorado State University. (Maxwell, 1978)

An important feature of Co-Tie is a state-owned data and voice communications network which links nine campuses to the CSU digital computer. Prior to this development in 1971, many junior colleges in Colorado were essentially without computing facilities for student use.

For years, some students have chosen to start their collegiate educations at small liberal arts colleges. Often, transfer arrangements are offered so that the student first attends the smaller college for three years and then transfers to a specified engineering college for two additional years of study. Successful completion of a three-two program results in the awarding of a B.A. degree usually in mathematics or science from the liberal arts college and a B.S. degree in engineering. The Illinois Institute of Technology recently entered into an arrangement with North Central College which is within the 35-mile radius of its ITFS system, IIT/V. Coordination of programs is enhanced through joint seminars so that students can enlarge their selection of courses before transferring.

High Schools

Many of Colorado's smaller and relatively remote rural high schools simply are unable to offer a complete set of pre-college mathematics courses because of the small numbers of students involved. While relatively large metropolitan high schools offer a wide range of required as well as elective mathematics, science, and computing courses, the curricula are "barebones" in most rural schools. For example, virtually no rural high school in Colorado has its own computing facility and offers computing classes.

In order to extend high school engineering programs and to provide some assistance to rural high schools, the Hi-Tie program was established in 1971. Through Hi-Tie, CSU has offered its freshman engineering course via videotape to senior students at any high school wishing to participate for the past nine years. During the 1979-80 academic year, approximately 25 students at 6 high schools earned university credit by taking the CSU freshman engineering course. The videotaped course covers basic Fortran IV programming and its engineering applications. In addition, five one-credit precalculus mathematics courses and a university mathematics placement examination are being offered to 50 students in 8 high schools. Taping is done in a studio-classroom with one section of CSU freshman engineering students.

Special sessions are included in the video series relating to "what engineering is all about." A number of campus groups such as the Institute of Electrical and Electronics Engineers student chapter and the Society for Women Engineers have made short videotape segments. Other segments address career opportunities and the life of the working engineer. The segments are edited onto the end of shortened lectures and are used as the advertisement of the day. Produced mostly by students, these special spots are effective in depicting the campus life of an undergraduate engineer to high school students. The high school students view the course tapes made at CSU on a regularly scheduled basis (Ward and Maxwell, 1975).

Programs such as these might well serve as an effective communications link between minority students attending high schools and universities. Because researchers often believe that high school is too late, other ways of supporting science and mathematics instruction in junior high schools and earlier need to be found as well.

Public Understanding of Technology

The NOVA television series shown over the Public Broadcasting System (PBS) is the best known and most long-lived example of programs designed to promote public understanding of technology. A new series produced with support from NSF and General Motors Research Laboratories is called "How about..." and features Don Herbert. (Herbert is known to most as "Mr. Wizard" from an earlier series.) "How about..." is produced in 90-second segments intended to be used in local news programming and "aimed at adult viewers who want to know more about how science and technology affect their lives - present and future." During 1978-79, 65 segments were produced, ranging over a wide variety of topics such as: "Mount Rainer, the Sleeping Volcano"; "3-D Pictures of Holography"; "Inside a Hand-Held Calculator"; "The Radar-Gun that Clocks Your Speed': and "Listening for Space Signals." The series first appeared in 1980 on 138 commercial television stations.

New technology can be very threatening in an established organization. Consider the general morale problems which might be encountered in the automobile industry as microelectronics is introduced. Assuming that the engineers can quickly assimilate the new technology through on-the-job training, what can be done to gain the understanding and approval of the support staff of the organization? General Motors/Delco Division purchased the introductory courses produced by Texas Instruments which describe solid state devices and give an overview of microelectronics. These video lectures are shown in the plant at various times. Everyone, e.g., secretaries, clerks, janitors, is encouraged to participate so that the new activities of the division can be better understood, and perhaps supported, by all (Holmes, 1978).

Foreign Programs

Many engineering colleges have participated in programs which involve assistance to foreign universities or various kinds of technical planning and development work for foreign governments. The activities of the International Division of ASEE attest to this commitment abroad. Clearly, many engineering faculty willingly devote several years of their careers to overseas work on the wide variety of activities required by foreign contracts. The faculty's personal encounters and experiences are probably essential. The extent to which ITV or other media can be used to enlarge the talent and resources devoted to such programs is an issue.

The University of Catania in southern Italy contracted with CSU to produce a course entitled "Management of Water Resource Systems: A Systems Approach." A team of faculty from each university developed the course outline, and eight CSU faculty shared in scripting the 30 hours of videotape and the companion text. The media production employs voice over a sequence of prepared graphics, film, and slides to illustrate the topic. An instructor does not appear on camera at any time. Sound tracks in both English and Italian were recorded on the original tapes; these have since been translated into two other languages as well. The course was finished in 1976, after two years of effort, and is now in use both on the campus of the University of Catania and in various government agencies in the arid regions of Italy (Baldwin and Davis, 1975).

Rogers (1975) reports on the development of a 40-hour program of technical training for use at Kam AZ, a gigantic automotive factory built with U.S. equipment on the Kama River in the Soviet Union. The C-E Cast Equipment Division of W.S. Tyler, Inc., contracted to deliver seven automatic molding lines for the sand casting of engine blocks and other parts to this factory. Each line is a hugh machine, approximately 200 feet in length, composed of mechanical, pneumatic, hydraulic, electrical, and electronic sub-systems. The U.S. contractor promised to supply instruction in the principles, operation, and maintenance of the devices. In the United States, this would be accomplished by presentations made by representatives of over 20 component suppliers, as well as the C-E Cast Equipment staff. A variety of slide sets, film strips, videotapes, working models, drawings, and catalogs would be used. Because of time and funding constraints, the decision was made to videotape each of these presentations in the ITV classrooms of Case Western Reserve University so that the entire series would be in a common, storable format. Both English and Russian sound tracks accompany the training course, which has been used both on this contract and in the United States. Rogers reports that about 4.5 hours of production time were devoted to each hour of instruction, which is remarkable considering the lack of experience of the 29 instructors.

Two on-going activities related to public health and irrigation water management have taken CSU faculty teams to Egypt and Peru. In each case, training of native technicians is an important part of the project. Videotaped courses from campus provide an academic supplement to the field training being carried out by the CSU staff abroad. The task of selecting the most able natives for additional education in the United States is eased by noting performances on the taped graduate courses, and the transition into American graduate school is less traumatic for the students selected for further education.

But, reliable, fast communications systems are necessary if the resources of U.S. campuses are to have a major impact on the foreign assistance activities of engineering and agricultural faculties. Two-way interaction is essential. Several multinational industrial corporations now routinely employ satellite teleconferencing to improve the coordination of widely dispersed activities. Satellites offer an unparallelled opportunity which has yet to be exploited in the education of professionals in their homelands.

III.
NEW TECHNOLOGIES

The "new" technologies discussed in this Chapter are recent applications of educational technology (ET) in engineering education. Modern communications on a large geographic scale by satellite has great potential as a logical extension of existing instructional television (ITV) programs. Several experiments and feasibility studies support this assertion. Secondly, advances in video technology coupled with powerful decentralization computing may make a new generation of instructional equipment affordable. This possibility offers great opportunities to engineering education, possibilities which are only now receiving serious study.

Satellite Applications and Potential

Engineering educators are pioneers in using media-based systems to provide educational programs for their employed professional constituents. In a recent study of continuing professional education in law, medicine, teaching, and engineering, the engineering profession was rated as "most promising as a market for electronic delivery of continuing professional education." It also was pointed out that "aside from their primary qualification as educational institutions, universities are 'neutral' organizations within a region, able to gain electronic entrance to, and disseminate information among, many corporations and thus precipitate an information flow which otherwise might not exist among competitors." (Rothenberg, 1975)

A communications satellite which is placed in geostationary orbit above the equator can provide broadcast coverage over about one-third of the surface of the earth. Thus, it is possible to expand educational television, radio, and data services from local or regional coverage to national or international coverage. The aggregation of large user groups receiving programming simultaneously leads to a delivery cost per viewer that is reasonable when compared with other communications options such as traveling to the point of program origin or mailing film or videotape.

Through the Association for Media-Based Continuing Education for Engineers (AMCEE), the engineering educators who pioneered the use of media-based programs for practicing engineers are actively studying all of the facets of using communications satellites to expand the number of courses and services to an even larger audience spread over a vast geographical area. The goal is to improve the quality of engineering education for the hundreds of thousands of engineers and scientists not presently receiving continuing education on a regular basis, while keeping cost at a level that is considered reasonable by both suppliers and users.

Current Status

The systems operating today fall into two major categories: 1) live transmission of courses from classrooms to companies over instructional television fixed service (ITFS) channels or over educational television (ETV) channels; and 2) mailed videotapes of either live or studio-produced instruction.

An ITFS signal has a broadcast range of about 30 miles. In areas such as Los Angeles or San Francisco, ITFS works well. Many high technology firms are located within range of the University of Southern California and Stanford University systems. In Colorado, however, because the terrain makes live broadcast impractical, Colorado State University (CSU) has built its off-campus program around a videotape distribution service. The Massachusetts Institute of Technology (MIT) has a program primarily based on a catalog of studio-produced engineering and science courses, and it depends on mail and parcel delivery services for worldwide distribution. Demand for certain of MIT's packaged courses is so high that, in one case, 20 complete sets of 21 tapes each are needed to meet circulation requirements. This alone represents an inventory investment of $15,000 to $20,000. The new tutored videotape instruction (TVI) program at Stanford permits students at locations remote from the campus to earn degree credit by viewing videotapes of Stanford lectures (Gibbons, et al., 1977). In the absence of the course instructors, tutors provided by participating companies assist students. The most troublesome aspect of this program is the slow delivery of homework and examinations to the Stanford professors. A minimum lag-time of one week must be built into the program to ensure stability in the viewing schedules at the remote sites.

These systems, while effective in reaching the well-defined constituencies of the producing universities, are generally unable to expand their services for the following reasons: technical, i.e., the signal can travel only a short distance for a reasonable cost; logistical, i.e., the mail and other delivery services are slow; and financial, i.e., a videotape inventory is expensive.

Because of its broad footprint, a communications satellite is capable of providing service which is effectively responsive to the technical, logistical, and financial constraints mentioned above. A signal can be transmitted from any single point to many receivers across the country without regard for distance or geographical barriers. The signal can be received simultaneously at all points in the system. Thus, given an aggregated user group, the cost per viewer of distribution can be substantially reduced.

Previous Experiments

The Educational Satellite Communications Demonstration was the first substantial federal investment in finding educational applications for communications satellites. Sponsored jointly by the National Aeronautics and Space Administration (NASA) and the Department of Health, Education, and Welfare, a series of three projects was operated during the 1974-75 academic year using the NASA-developed ATS-6. Color television was distributed by this high-powered satellite to small antennas at rural schools and other, similar sites. The three regional projects included the Appalachian Educational Satellite Project conducted by the Appalachian Regional Commission, the Satellite Technology Demonstration conducted by the Federation of Rocky Mountain States, and the ESCD/Alaska conducted by the Alaska Governor's Office of Telecommunications. Between $18 and $34 million (depending on how much of the satellite and launch costs are included) was spent on these demonstrations. The Educational Policy Research Center of the Syracuse Research Corporation reported extensively on the results of these projects (Educational Policy Research Center, 1976).

During the 1976-77 academic year, Stanford University in California and Carleton University in Ottawa conducted a curriculum-sharing experiment using the Communications Technology Satellite, an experimental high-powered satellite co-sponsored by the United States and Canada. Three objectives were identified: 1) to demonstrate the ability to expand the scope of instruction by sharing classes between universities with different emphases and orientations; 2) to develop optimum class presentation and student/teacher interaction techniques for remote curriculum sharing; and 3) to develop, demonstrate, and evaluate a cost-effective, digital video compression system in conjunction with efficient channel coding and modulation.

The experiment was designed to take advantage of in-place equipment. Stanford had been operating its four-channel ITFS network since 1969, and Carleton had set up a "Wired City" laboratory containing an array of television-communications equipment. During the two-quarter experiment, four courses and one seminar were sent by Stanford and three courses were provided by Carleton. Sharon Strover of the Institute for Communication Research at Stanford reported:

> What does the Stanford-Carleton-NASA-Ames curriculum-sharing experiment mean for the larger contingent of satellite users and satellite watchers? Is it a promise for the future or just another "ho-hum" in educational technology? Our conclusion must be somewhere in between these poles. The digital video operated well, promising more efficient use of bandwidth in the future;

> serious scheduling and accreditation problems were avoided; students were by and large satisfied with the courses; and the project sustained satisfactory operations from October 1976 to March 1977. Curriculum-sharing proved, at least in this case, not to be the administrative hassle one might think. While unforeseen costs did emerge at Stanford, burdening the Instructional Television Network, it was, after all, part of the project's goal to uncover such expenses. On the other hand, the full potential of resource sharing was not tapped in this project. Further experimentation must focus on the interaction capabilities of this medium within an educational setting, evaluating obtainable results in light of other mechanisms offering similar "results." Hence, curriculum-sharing via satellite must still be phrased in terms of potential. (Strover, 1978)

Another recent experiment in graduate engineering education using the Communications Technology Satellite involved North Carolina A&T; Jackson State University, Mississippi; Stanford University; Bell Northern Research of Canada; and the Rockwell International Science Center. In this two-day activity, graduate students and faculty members of two institutions with large minority enrollments had the opportunity to present and receive technical reports on high-level research projects. Two-way video and audio channels permitted face-to-face interaction between participants on the east and west coasts.

The above experiments were really demonstrations of potential long-term satellite applications. At a "Conference on Educational Applications of Satellites" sponsored by the National Institute of Education (NIE), Lawrence P. Grayson, Chief of the Technology Applications Division of NIE reported that the Institute would commit itself to a second major program of support for satellite applications. "The purpose of this program is to identify uses that can meet existing educational needs, to demonstrate that the costs can be kept low enough to be afforded by the users, and to assist a number of organizations through the transition from having shown that satellites can be useful in meeting the needs of their constituencies to implementing operational services." (National Institute of Education, 1977) In this context, representatives of media-based engineering education programs have been developing a plan for implementing an operational satellite delivery service.

An Operational Plan

Past and present programs of media-based systems will have a strong influence on the development of future services provided by satellites. The engineering profession can look forward to starting with an already tried and tested educational service that will be expanded and enhanced through geostationary satellites having broad coverage. Televised engineering education is currently reaching a numerically large, but relatively small proportion, of the population of over one million working engineers. However, the future satellite-based delivery service will:

- Deliver regular classroom subjects, generally engineering and science courses at the graduate level, beyond present regional boundaries served by ITFS, ETV, and slowly delivered videotape;
- Deliver more studio produced, packaged courses to larger numbers of users on a timely, efficient basis; and
- Deliver novel, special programs such as short courses, seminars, speeches, and emergency engineering-related notices which are not now being made available for national distribution because of the financial constraints imposed by relatively small local audiences.

Though a centralized system, the satellite will permit video broadcasting of classroom instruction from major American universities to employed engineers at industrial plants and research laboratories thoughout the country. It also will permit curriculum sharing and curriculum enrichment by providing smaller or developing institutions with access to major university programs. It is anticipated that many such institutions will want to supplement their curricula. For example, the Oregon Graduate Center currently lists videotaped courses from Stanford and MIT in its descriptive literature.

In addition to the video broadcasting described above, the system will permit the transmission of examinations, lecture notes, and homework assignments on a subcarrier that will be demodulated and reproduced separately at each receiving point, thus producing hardcopy. With this simple system, up to 15 pages of written or printed material will be transmitted with each hour of video broadcasting. By one estimate, there are 200,000 facsimile copiers now in use, and such rapid growth is anticipated that over 500,000 are expected to be in use by 1985. This technology will prove important in the implementation of national and international education programs by satellite.

A data and document retrieval service also will be provided for each participating university and industrial subscriber. Initially, a telephone line data terminal will be used to access computer-based library services and national data banks. A national data bank of engineering educational services such as abstracts, catalogs of courses, and consultant services will be accessible through this system. Data which have been requested will be returned over the telephone line, or a document will be sent from a video-transmitting university at the same time as the classroom broadcast by means of the facsimile machine and subcarrier channel mentioned above. Other new satellite-based data transmission systems will be explored as they become available.

Two-way teleconferencing also will be possible with a satellite system. Two satellite channels will be required whenever face-to-face conferencing is needed. It is anticipated that teleconferencing will lead to more effective coordination of many projects and programs among universities. Indeed, some believe that only in this way can the full benefits of a national educational consortium, such as AMCEE, be realized. Currently, key university administrators travel to occasional meetings then return to their home institutions to relay plans, but the satellite system will enable working groups of dispersed faculty and industrialists within a single discipline to undertake planning and evaluation sessions on a continuing basis. Teleconferencing also will allow people at widely separated locations to interact in technical seminars.

Programs will range from standard 30- to 40-hour graduate level engineering and science courses to short classes of five to ten hours duration. Transmission of live courses will take place during the six-hour period when east and west coast universities are in session (11 a.m. - 5 p.m. Eastern Time; 8 a.m. - 2 p.m. Pacific Time). During the other available hours, prerecorded materials will be transmitted for off-the-air recording and use at a convenient time.

Anticipated Satellite Configurations

There are two fundamental system models under consideration: 1) the independent system in which the satellite transponder connects program originator and users directly, using only originator-user owned uplinks and downlinks as shown in Figure 5; and 2) the dependent system in which part of the system belongs to another agency such as the National Public Radio (NPR) of the Public Broadcasting Service (PBS) as shown in Figure 6.

With the independent system, one university will send a signal through a satellite directly to other universities and participating company sites. A receiving university might then retransmit the signal over its local system. The dependent system will be tied to PBS earth stations (both radio and television) located on or near university campuses. Programming will be sent and received through shared terminals, with university-owned control centers handling the preliminary origination and the subsequent distribution of the sent and received signals.

A combined system in which shared and independently-owned terminals are used is technically possible also. The choice of independent, dependent, or mixed systems will depend on the availability and costs of the satellites and related components. Currently, a major political-corporate struggle is underway to determine the appropriate uses of available frequencies; the outcome of this will have a significant impact on the direction of all future satellite services in the United States. Therefore, engineering educators are in a "wait and see" mode in their planning at the present time.

Economic Factors

The media-based university engineering programs generally consider only the capital costs and day-to-day operating costs of their broadcast or videotape systems. Faculty salaries are covered by the university budgets and are not included in the media-based system

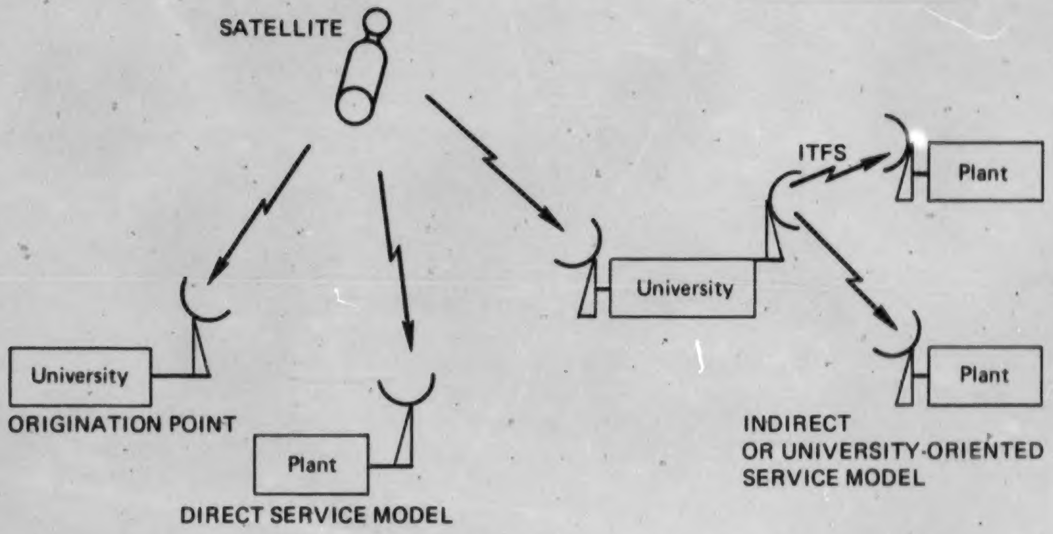

SATELLITE
ITFS
Plant
University
University
ORIGINATION POINT
Plant
DIRECT SERVICE MODEL
Plant
INDIRECT
OR UNIVERSITY-ORIENTED
SERVICE MODEL

FIGURE 5 Independent system model.

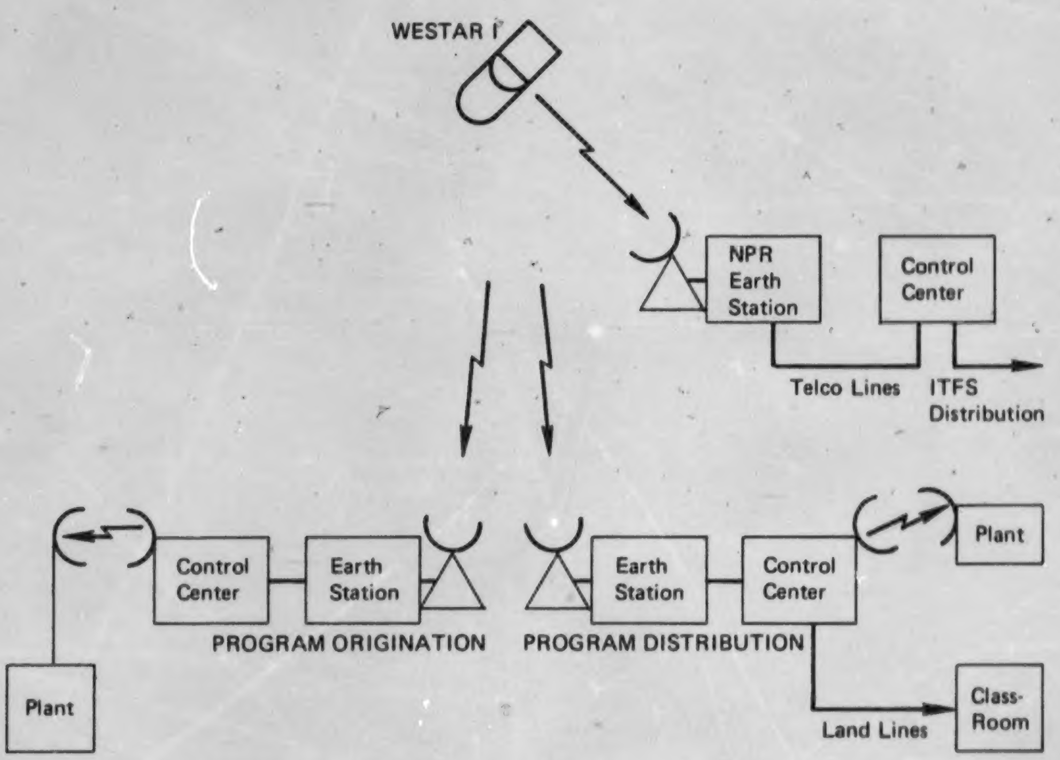

WESTAR I
NPR
Earth
Station
Control
Center
Telco Lines
ITFS
Distribution
Control
Center
Earth
Station
Earth
Station
Control
Center
Plant
PROGRAM ORIGINATION
PROGRAM DISTRIBUTION
Plant
Class-
Room
Land Lines

FIGURE 6 Dependent system using national public radio.

costs. Adding a satellite delivery mode on top of the current systems requires careful cost analysis, as the hourly transponder fee can range from $100 to $1,000. The earth terminal equipment cost also must be taken into consideration.

If one assumes a satellite rental fee of $300 per hour, a course fee of $50 per hour, and that 20 percent of the course fee ($10 per hour) would be set aside to cover the satellite cost, then a minimum of 30 subscribers is needed just to cover the satellite rental cost. It is clear that large aggregated audiences are essential for the system to be economically viable.

An issue currently receiving attention is the role of the federal government in fostering the development and utilization of communications satellites in public service areas, including education. The Committee on Satellite Communications of the Space Application Board of the National Research Council (NRC) recently published a report on this subject. The Committee did not recommend that the federal government, i.e., NASA, provide and operate a public service satellite communications system. However, it strongly supported the option in which "NASA and appropriate user agencies would jointly define, develop, and test (including flight demonstrations) new public service satellite communications systems. In addition, NASA and the user would be jointly responsible for transferring the new system to the appropriate operating agencies." (Committee on Satellite Communications of the Space Applications Board, NRC, 1977)

At this point, it seems that the community of engineering educators developing the plan for an operational satellite delivery service can foresee a break-even or profitable operation in a relatively short amount of time (assuming that marketing projections are valid and counting only hourly satellite rental fees). However, the initial capital required for such a system will be approximately $2 million.

Experience is the primary difference between the operators of media-based systems for delivering engineering education and other public service groups who are seeking federal support for the development of satellite-based systems. Most of the managers of the in-place engineering education systems have operating experience of five to ten years behind them; they are seasoned veterans. They are familiar with the problems of putting course schedules together, distributing them, and enrolling students. They know the costs of high quality media-based instruction, and they know that they depend on income from satisfied users for survival. They have experience in dealing with university administrators and faculty, industrial training directors, engineering managers, and engineering students of varying ages and abilities. This is the single most compelling argument in favor of immediate federal support for the development of a nationwide satellite service for engineering education. Diffusion of the technology to other areas of higher education then can proceed.

Video/Computer Combinations

Despite the rapid decline in the cost of hardware for computing, expenditures in this area by institutions of higher education have not declined. Nevertheless, in computing, the past will probably not be a good guide to the immediate future because the affordable alternatives are multiplying rapidly.

Advances in semiconductor technology have caused incredible changes in the last decade (Flanagan, 1977). Whitney (1977) put these advances in economic perspective as shown in Figure 7, noting that "it takes about 2,000 gates to make a four-function calculator, about 8,000 to make a 16-bit minicomputer, and about 40,000 to make a medium-scale 32-bit computer." His conclusion is generally regarded as true:

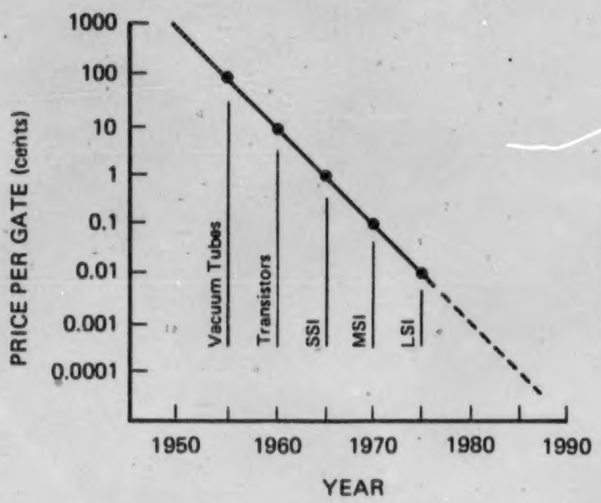
> The point of all this is that semiconductor technology is advancing at such a rate that, even before 1980, the cost of processor electronics will not be important. There will be new rules by which to play the computer design game. We must think creatively about what to do with "zero cost" logic. (Whitney, 1977)

In early 1975, computer kits were marketed for about $340 in what might be called the first wave of *personal* computers. Over 400,000 microcomputers have been sold since then. "Dozens of companies have entered the marketplace with new computers, terminals, disc drives, speech synthesizers, D/A and A/D converters, audio-cassette-recorder interfaces, graphics systems, and other related devices." (Braun, 1977) Today, several computers are being retailed for approximately $900, assembled. These are complete microcomputers with a large-capacity memory, a video monitor, a keyboard, and an audio cassette recorder, all with interfaces, plus the usual processor and power supply. These second generation personal computers feature BASIC, but other computer languages such as FORTRAN IV, APL, and PACAL are readily available. They were on the market two years after the first generation. A wide array of compatible peripheral hardware are available which plug into the unit. For example, a popular color graphic device consists of a single board costing $350 with a definition of 128 x 128 (horizontal x vertical) picture elements which permits the choice of eight colors on a TV monitor in two intensities (Dwyer and Sweer, 1976). Personal computer manufacturers were the star electronics performers of 1979; the three major competitors each more than doubled their output.

Hardware is just part of the revolution. Other evidence includes:

- Publications aimed at the computer amateur and educator: *Byte*, *Dr. Dobb's Journal*, *Kiloband*, *Personal Computing*, *ROM*, *Creative Computing*, *People's Computer Company*;
- Computer retail stores;
- Computer clubs; and
- Personal computer shows such as the first one in Atlantic City in August, 1976, which drew 5,000 attendees.

Table top machines with the power of an IBM 1620 now retail for under $2,000. By mid-1980, an IBM executive has promised one-third the power of an IBM 370/168 "under a keyboard."



SOURCE: Whitney, 1977.

FIGURE 7 Costs of logic gates.

Concurrently with the microprocessor innovations outlined above, progress is being made on videodisc systems targeted for the consumer marketplace. These laser-powered recording systems employ digital signal storage and retrieval which provides data or image storage density that far exceeds that of magnetic recording. "Playback only" optical disk storage systems are available now which offer an economic savings of at least 20 percent compared to other mass frame storage media, e.g., microfilm, microfiche, and film strips. Furthermore, the same disk can store computer codes for interactive electronics and other functions. The principal problem with these first systems is the "read only" memory feature that not only precludes easy editing when used in an interactive CAI authoring mode, but also makes reproduction runs of 100 or more copies necessary if the "playback only" disks are to be competitive in cost with video cassettes for film storage (Schneider, 1977). These shortcomings are recognized, and development work is underway in a number of laboratories to produce laser-powered recording systems with instant playback as a medium for high-speed, mass data storage (Bartolini, et al., 1978).

The promise of inexpensive, rapidly accessible, massive videofiles coupled with the rapidly developing microcomputer technology is stimulating renewed interest in the use of these technologies for educational purposes. An essential new ingredient is the orientation of the device manufacturers toward direct consumer purchase.

Current Status

Many university presidents may welcome the consumer takeover of computing. As shown in Figure 8, the central university computing facilities in the United States spent over $991 million during 1976-77, up from $472 million in 1969-70 (Hamblen, 1977, 1978). Figure 8 distributes these amounts by major computer functions, i.e., instruction, research, and administration. Note the huge increase in dollars over a three-year period. Also note that administrative expenditures grew appreciably faster than instruction and research expenditures. Eighty-two percent of the computer costs for the 1977 fiscal year were paid through the funds of the individual institutions, 7 percent was paid by the federal government agencies and 11 percent by other sources.

The fourth inventory of computers in higher education sponsored by the National Science Foundation (NSF) has just been completed. Table 5 shows the types of instructional use of computers that were reported (Hamblen, 1980).

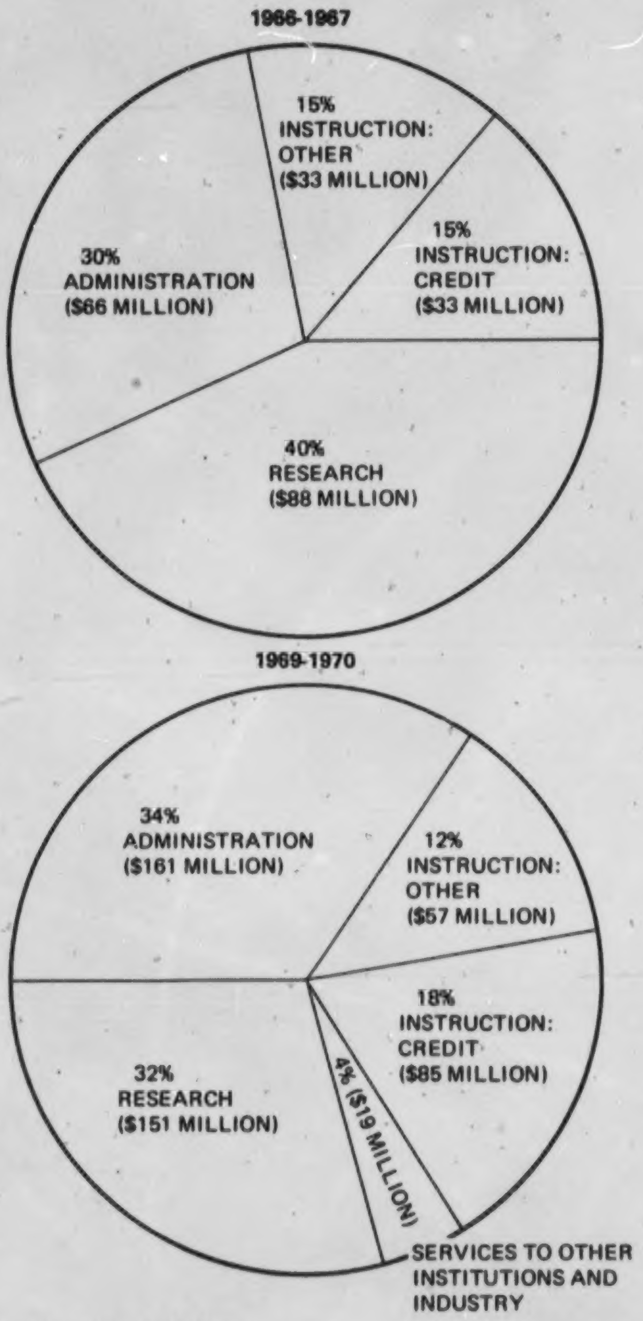
TABLE 5
USES OF COMPUTING IN ENGINEERING EDUCATION

No. of Institutions Reporting	Type of Use
238	Problem solving
136	Simulation
29	Computer-assisted testing
43	Computer-assisted instruction
10	Computer-managed instruction

Source: Hamblen, 1980

Table 6 shows that the cost of computing services for engineering students in courses which required a computer rose from $45 per student in a course in 1969 to $71 per student in a course in 1976. Note that engineering is now the most expensive discipline per student in a course, but lags behind computer science and business in total resources demanded.

Although not shown in Table 6, Hamblen reports a slight drop in the number of courses (12 percent) and engineering students (22 percent) in 1976 as compared to 1969. On the other hand, the total resources consumed climbed from $10.9 million in 1969 to $13.3 million in 1976. Both trends are puzzling since computing costs are clearly decreasing and total engineering enrollments have risen sharply during the interval. It should be noted, however, that the survey response rate also dropped from 75 percent in 1969-70 to 58 percent in 1976-77, and no attempt was made to extrapolate the data. Indeed, an interpretative analysis of these data on computing in instruction is not yet available; inquiries may be directed to Carl Zinn, University of Michigan.



SOURCE: Hamblen, 1977.

FIGURE 8 Estimated Distribution of Expenditures for Instruction Research and Administrative Uses of Computers in U.S. Higher Education 1966-67 and 1969-70.

TABLE 6
COST PER STUDENT PER COURSE FOR VARIOUS DISCIPLINE AREAS, 1969-70 and 1976-77

Discipline Area	Number of Courses 1976-77	Number of Students 1976-77	Value of Computer Use (in Millions) 1976-77	Cost per Student per Course 1969-70	Cost per Student per Course 1976-77
Computer Science	8651	292,921	$17.2	$78	$59
Engineering	7356	187,877	13.3	45	71
Business	5320	259,003	14.8	44	57
Math/statistics	3716	125,145	4.8	42	38
Physical Sciences	2418	84,053	3.1	45	37
Social Sciences	3090	85,621	2.3	36	26
Education	1088	31,292	.7	27	24
Environmental and Life Science	2408	69,825	1.8	--	26
All Other	3962	133,175	5.1	54	38

The above table shows the numbers of courses that involved computer usage during 1976-77, the numbers of students enrolled in those courses, and the value of the computer services by discipline area. These figures are based upon report summaries and are not extrapolated estimates; the 1969-70 survey had a 75% response rate and the 1976-77 survey only a 58% response.

Source: Hamblen, 1980.

The cost of hardware amortization during the 1976-77 academic year is 40 percent of the cost of computer services cited above. The personnel support services for the computing facilities, maintenance contracts, expendable supplies, and software purchases generally take the other 60 percent. These costs of ownership also will shift to the individual, or perhaps in the initial stages of transition, to the academic departments in which the new computers will reside.

The early stage of this shift of ownership is already evident on many campuses. Some major university research users of computers are now purchasing very advanced minicomputers to perform rather large simulation calculations, as well as for special-purpose data reduction (e.g., Lykos, 1977). Some of these machines are linked to the central computing facility by telephone or cable. It is reasonable to expect that the new personal computers, which will be capable of performing many of the instructional computation tasks assigned to students, also will be interconnected with central computing facilities when the need arises (Zinn, 1980). Organizational problems centering around funding patterns and operational control will probably increase temporarily as the process described above spreads and evolves. However, just as the introduction of paperback books shifted ownership of some supplemental readings into the hands of students without closing the university libraries, central university computing facilities can be expected to thrive on administrative and interactive services. Some large data bases and simulations used in instruction also will reside in such centers. However, the trend is clearly toward decentralized computing for instruction.

Some of the major instructional applications of computers with particular emphasis on computer graphics and the potential of the videodisc should be highlighted. These will be discussed as useful variations on the three instructional goals of ET mentioned earlier: 1) to lower costs; 2) to individualize instruction; and 3) to provide unique experiences (Hooper, 1974).

Computers to Lower Costs

Today, few people seriously consider lowering costs an argument for computing in instruction. The early literature abounds with cost-effectiveness discussions, but any honest comparison of computerized teaching costs with conventional teaching costs per hour are disappointing, perhaps by a factor of three in the recent past. University-based advocates generally employ "anyhow" accounting--"we are going to do it anyhow"--when discussing costs. Perhaps the most honest cost quote of the day is that from Control Data Corporation for its Programmed Logic for Automatic Teaching Operations (PLATO) service; it is fogged only by a disregarding of the early federal investment of over $15 million for system development. A monthly lease of a single PLATO terminal with all interconnections and curricula-use charges is about $1,000. If used at a normal rate of 125 hours per month, the resulting cost is approximately $8.00 per student-contact-hour. Using effectiveness as an argument is only partially successful, since the results have been mixed in the larger computer instruction projects as will be discussed later. However, few educators doubt that there are gains to be made in this area. Hooper (1974) notes that assessing "cost-effectiveness is, after all, only a means to an end" and "cost-effectiveness arguments generally, are a mine field of good (and bad) intentions."

The latter point focuses on a major failing of government procedures with regard to computers in education to date. No sustained effort to enlarge the numbers of educators working on computer applications has been undertaken recently. Less then 5 percent of the nation's engineering colleges now receive external support to explore these issues on a broad scale over time. Rather, until recently, two large projects (PLATO and TICCIT) have commanded virtually all federal support for almost a decade. Now, these programs also have been forced into the marketplace. The initial selling rhetoric for these large-scale projects was "cost effectiveness." If we have learned from this recent experience, we will not force educators who seek to apply computers to instruction to make premature cost savings claims again.

At the local level, universities treat computing as an add-on cost to traditional instruction. The issues are: 1) what can be afforded; and 2) how to get the best utilization of the central facility. The value of computing in instruction is generally conceded without much study. All major institutions support major computing facilities.

Computers to Individualize Instruction

Active learners interacting with a computer-based tutor that can diagnose and test, as well as quickly present a variety of sequences of instruction, is the goal of computer-aided instruction (CAI) and, to a lesser extent, computer-managed instruction (CMI). The approach builds on the research on the early programmed learning machines but adds the flexibility of massive computer record keeping of individual performance. Thus, CAI also promises interactive course authoring based on student performance data. Merrill (1971) discusses the components of a cybernetic instructional system in a general manner.

Sugarman (1978) reviews the state of the art in practice with illustrative examples.

> The lure of computer-aided instruction (CAI) is once again being felt by those who have maintained their interest in this problem-ridden educational tool and believe that advances in the technology will give it another chance. In the late 1960's, it was supposedly going to revolutionize the learning process; the best teachers were going to write "courseware" (interactive education computer programs) that would be nationally distributed. Students would learn rapidly and efficiently. However, reality turned out to be quite different from the dream - so far.

> A few people did take the time to study the medium's potential and did produce outstanding computer educational material. But, CAI development, which has remained in the hands of a relatively small community of experts, has yet to develop as much courseware as had been predicted. Except for grade-school drill and practice, it also has yet to overcome the general reluctance of the educational community to adopt it on a wide scale. (Sugarman, 1978)

Appendix D reproduces Sugarman's article, "A Second Chance for Computer-Aided Instruction: What Networking Promised But Didn't Deliver May be Developed at the Local Level as Hardware Costs Drop." It provides a good summary of the status of CAI today.

A 1967 review (Bushnell and Allen) cited 26 CAI/CMI projects underway at the time. Sugarman's 1978 review cites only nine programs. Perhaps the most refreshing change promised by inexpensive, widely distributed hardware is the opportunity to expand greatly the number of educators involved in CAI and CMI. The educational benefits of such an expansion would not be limited to a more rapid dispersion of CAI in institutions; it also would provide many educators with experience in one of the most demanding ET tasks, the creation of CAI courseware. Interactive authoring of CAI materials based on detailed student performance and attitude surveys maintained by the computer cannot be simulated in other media. Furthermore, the computer format requires explicit organization which can be audited and transferred. In principle, the PLATO program allowed this authoring experience to be dispersed, but cost and other constraints have prevented wide-scale exposure. The federal government should undertake a sustained program of funding which would allow educators, particularly those in the engineering and physical science areas, to experiment with the production of CAI courseware. Such a program should support the operating expenses associated with the necessary research, as well as prototype equipment purchases. At an annual funding level of $90 million, a well-managed program could stimulate many fruitful joint ventures between educators and equipment manufacturers.

From Table 1 of Appendix D, note that work is now underway to develop a stand-alone PLATO V terminal. Similarly, Heuston (1977) reports on work underway by TICCIT developers to produce a demonstration of biology instruction on a new videodisc player coupled to a microprocessor and keyboard. Perhaps, the conversion of the existing courseware to new, stand-alone machines is logically a first step. The evaluation results are not persuasive however (e.g., Alderman, et al., 1978, with responses), though students clearly "like" the computerized instruction (e.g., Magidson, 1978).

Results from a program employing randomly accessed video frames from a disc and ITV from a tape were reported by Hayman and Lord (1972). This computer-managed instruction (CMI) system used a computer-based management strategy formulated from the taxonomy of Bloom (1956); a mini-computer interface to mass storage (CDC 6400); a rotating video memory disc to provide 450 video images on the top surface and a flying head to search for the required image, and to transfer the signal to the underside of the disc where a fixed buffer-head transferred the signal to a TV monitor at the student station. Brief videotaped presentations were stored on a videotape player modified to allow random access and remote control. Although it was constrained by yesterday's hardware, this development work also is a point of departure for other engineering educators who seek to combine video and computing for individualized instruction today.

The real promise of the videodisc coupled with a microcomputer is decentralization. If the hardware costs do not dominate, then computer-based courseware production can be widely explored. Recall that ITV hardware costs represent only a small fraction of the total cost of video-based instruction. Therefore, inexpensive, local courseware development flourishes. Yet, very elaborate ITV productions by the BBC for the Open University also can be justified; these cost 10,000 times more than a candid classroom production. Now that hardware costs do not demand centralization, policy-makers should encourage wide exploration of computer courseware development procedures. The pool of educators seriously interested in the application of computers to instruction would be enlarged most effectively by this strategy.

In late 1975, the NSF sponsored a workshop entitled "Ten Year Forecast for Computers and Communications: Implications for Education - 1985." The resulting publication (Seidel and Rubin, 1977) has thoughtful articles on the impact of large-scale, integrated circuits and storage technology on educational computing systems, as well as the impact of improved interfaces with the learner. S. Papert (1977) gives a seductive argument on learning environments for children, and he concludes:

> Surely I have said enough to make the point that formulating the task as design for education in a technologically rich future leads very quickly into areas of research which are totally neglected, indeed quite unsuspected, by the community of professionals in 'education research and innovation.' There must in the world be tens of thousands of people struggling to understand what happens in a classroom where children are asked to do sums with pencil on square paper. Some of them try to improve matters by having the children do the same sums on computer terminals. I do not think it is my business to criticize or judge the value of all this. But I cannot help being overwhelmed by the fact that there must be ten thousand or more people doing that for each one person who has the other kind of design process of which I have tried to give you a glimpse. And I suggest that what happens in ten years depends very sensitively on whether our society decides that it can afford a small shift in this ratio. So perhaps the problem is more political than technological. And if the political aspect depends on how well we can convey an alternate vision, then perhaps it is even more poetical than political. (Papert, 1977)

It is worth noting that the British apparently have decided on CMI as the most promising route. In CMI, of course, the computer may be on the periphery of the learning process; rather, the computer is employed as a manager. Records are kept and tests are given, scored, and analyzed. Students are routed through course modules on the basis of learning ability.

> Computer based learning is now entrenched in the UK; the question is no longer whether it will happen but how it will evolve. The major factor is cost. Software and hardware are expensive. Computer assisted learning and computer managed learning are add-on costs, like audio-visual aids and educational television. Notwithstanding, the government is betting on them. The Council for Educational Technology has been given a four-year follow-on grant from the government to disseminate and coordinate computer assisted learning and computer managed learning, so clearly there is interest in maintaining the momentum. (Adams, 1978)

Some of the old distinctions between CAI and CMI are fading. For example, a national conference on CMI held in Chicago in November, 1974, spent considerable time debating the distinctions (Mitzel, 1974), and the first PLATO Courseware Catalog (CDC, 1978) contains courses employing PLATO, videotapes, and printed texts.

A review of the research results from CMI was given by Hawkridge (1974). An excellent example of CMI in medical education is reported by R. E. Pengov in the proceedings cited above (Mitzel, Part II, 1974). Pengov describes the Ohio State University College of Medicine CMI system, which is used as a supplemental instructional tool on campus, as a continuing education delivery system for 15 other locations, and as an alternate path through some basic science courses for medical students. In the latter mode, CMI is popular with students for the time savings it allows through self-pacing.

Word processing offers another example of computers to individualize instruction. In the last few years, the offices of many engineering groups in industry and government have added equipment and supporting software to assist in the preparation of reports, specifications, and many other documents. University faculty engaged in research are increasingly employing similar equipment, and in the near future they will surely be attracted to the application of word processing to assist student engineers in the preparation of assignments. The automatic recognition of misspelled words alone will relieve the instructor of a time consuming task. Many other features of word processing are sure to be exploited by faculty who have this equipment to assist them in their work.

Computers to Provide Unique Experiences

Engineering education abounds with examples in which computing does, indeed, provide unique experiences. Hooper attempts to catalog these as follows:

> - Get first-hand experience of more realistic problems and experiments, without the student getting bogged down in mathematics and data analysis;
> - Explore and practice numerical approaches to problem solving, thus complementing traditional analytical procedures, and, given these numerical techniques, the student can then tackle the more realistic problems;
> - To integrate different approaches and disciplines in an authentic, multivariate, simulation model;
> - To develop skills of synthesizing as well as analyzing (circuit design may be best learnt by designing circuits rather than analyzing circuits already designed);
> - To close the gap between theory and practice, lecture and lab session, by being able to manipulate in practice theoretical concepts, changing, for example, the input values and parameters of a given model to test a given hypothesis;
> - To develop problem-solving skills particularly with regard to decision-making, for example in the planning of scientific experiments or in the carrying out of a medical diagnosis; [and]
> - To perform simulated experiments which are expensive, dangerous, time-consuming, impossible to do in the normal science teaching laboratory. (Hooper, 1974)

Clearly the above partial listing of unique educational experiences made possible by computing illustrates the almost endless variety of instructional goals which could be catalogued. In the opinion of the authors, these educational uses of computers are both the most fruitful and, from the point of view of external support, the most neglected applications of computing. The examples provided in the following subsections are illustrative only and are given in the hope that they will convey some of the excitement which knowledgeable experts share for the role of computing in providing unique learning experiences.

Problem Solving, Simulation, Laboratories: If personal, or at least much less costly, computing systems become widely dispersed in engineering colleges, the faculty who would direct the use of these facilities to improve instruction could profit from the following insight.

> For the undergraduate curriculum in mathematics, physics, and engineering, and most other sciences, the maximum return on a modest investment of developmental effort comes from work in problem-solving, simulation, and laboratory data analysis, in that order. Furthermore, I contend that work in these computational uses leads to a qualitative improvement in the

> teaching of the essential subject matter of these courses, in that it makes some central concepts possible to teach that were not possible or very difficult before. Third, I contend that these three categories of use develop in the student a sense of mastery of a powerful general tool. And, finally, I contend that these uses, which are student-dominated rather than computer-dominated, are more in keeping with the liberal tradition of inquiry. (Luehrmann, 1971)

Outside of science and engineering education, one might sustain an argument that computers must be programmed by teachers to become a part of the educational process. However, the very practice of engineering is being changed dramatically by computers, so student proficiency in computing _per se_ is a universal goal.

Affordable, stand-alone hardware has the potential of improving the transferability of courseware from institution to institution. The cost of courseware development will progressively become the dominant cost of computing, because hardware costs are rapidly declining while labor-intensive courseware is becoming more expensive. Perhaps the day will come when, in order to transfer an attractive instructional program, an educator will simply purchase the specific machine employed by the developer and negotiate a lease or purchase of the desired courseware. This approach would assure transferability. Of course, this approach is essentially the inverse of all efforts to date, such as CONDUIT (1977).

To guide educators through this transition, federal officials should design a number of new programs aimed at encouraging the transfer of courseware. These diverse efforts might include sponsorship of the following: consumers' unions to evaluate courseware which is operational on specific machines in specified disciplines, and to publish findings (Braun, 1977); lectureships to enhance personal knowledge transfer among educators in a discipline who are in different institutions; workshops and summer institutes for faculty at leading regional institutions; and media-based, short, packaged courses for educators to use for in-service training, with laboratory experiences designed around popular stand-alone equipment.

The initial impact of the personal computers may be centered in high schools. The efforts of Truxal and Braun, SUNY-Stony Brook, to influence minority students in grades 9 though 12 was mentioned earlier. They have found that simply making a personal calculator available on loan to minority students in Chicago high schools (with no formal instruction) stimulated a very significant improvement in mathematics performance (Diehl, 1978). Others have reported similar findings (Suydam, 1978). More recently, Truxal and Braun have been experimenting with PET 2001 microcomputers in three Chicago high schools, and, in one instance, the machine is transported from the school to a neighborhood youth center after-hours and on weekends.

In the simulation mode, the computer becomes a device to simulate physical reality in the form of governing equations, laboratory experiments, or probabilistic processes. Thus, simulation applications of the computer can be as varied as the historical role of experimentation has been in the education of engineers. The computer is, of course, not a substitute for some real laboratory experiences. Instead, the simulations are most effective when coupled with traditional experiments to provide experience with a wider range of variables or to illustrate theories about microscopic behaviors that are not directly observable. An outstanding example of the power of computing in improving microscopic insights was published by Rahman and Stillinger (1971). This pioneering effort to simulate liquid water at the molecular level has stimulated many more investigations on the modeling of matter (e.g., Lykos, 1978b). In this same vein, Deardorf (1970) simulated three-dimensional turbulent channel flow using the basic time-varying equations of motion to provide a detailed insight into this complicated phenomenon, an insight that was not available before the advent of today's computing power. Computer-generated movies or videotapes may be used to summarize this research work for students (Science, 1978). And, in the future, expanded capacities in local computers may enable classes to interact with these models in a laboratory manner as well (Wilson, 1975).

The gap between industrial practice and the university laboratory is widening rapidly. The emergence of powerful new measuring instruments and control devices is outpacing the equipment budgets of universities. Each of the new industrial instruments has a microprocessor and digital memory as an integral part of the device. Many of the instruments have built-in data analysis programs which alter the traditional lab procedures fundamentally. These same instruments are being employed by engineers in practice to assist in the automation of industrial processes and machinery (Oliver, 1977). Indeed, young graduates with skills in the applications of these "intelligent" instruments are in greatest demand today. Yet, unless more effective funding mechanisms are developed, the engineering colleges will become progressively more poorly equipped to offer instruction with modern instrumentation. This hardware problem should be addressed by industries concerned with the manufacturing and application of the new generation of instruments. Perhaps the National Research Council could study the issue and make recommendations for needed actions, such as new government incentives to bring university instruction in this area up to acceptable standards.

Combined Media for Case Studies: Bell and Brenchley (1972) use the case study approach to involve students in community environmental problems. They created a data base for a reference community to defuse local political implications and to minimize time lost searching for data. The case contains 200 pages of descriptive information on such topics as government, public works, health and welfare, socio-economic conditions, climate, commerce and industry, and recreation. The file also contains 25 figures and 46 tables. Historical data trends are given, and city and county environmental health ordinances are included. This rather massive file is used as the basis for several computer simulation games:

- Air pollution - "Air Quality Display Model," (Environmental Protection Agency, Washington, D.C., 1969, there are later versions of APEX as well);
- Water quality - "Simulation of Water Quality in Streams and Canals - DOSAG-1," (Pub. 202-974, Texas Water Development Board, September 1970);
- Solid waste management - "DISCUSS - A Solid Waste Management Game," (A.J. Klee, IEEE Transactions, Vol. GE-8, No. 3, July 1970).

The integration of these activities into a common, transportable format requires massive data and program storage. The entire effort might be given additional motivational impact by selective use of ITV. Instructional programs such as this are good candidates for videodisc systems.

Interactive Graphics: Computer-aided design (CAD) is a unique experience that is hard to simulate without interactive graphics. Most computers today are operated in a batch-job environment for economic reasons. This may maximize machine utilization, but it can result in very inefficient use of human intellectual power. Braun (1977) likens it to "blowing into a clarinet or plucking a banjo string and waiting till tomorrow [be fair: a half hour!] to hear the note you played!" When interactive computing is aided by graphic displays, the learner or designer has a powerful tool (Bork, 1974). The research literature is not convincing in this matter, but few educators doubt the effectiveness of graphic presentations. The major deterrent to utilization to date has been the relatively high cost of hardware for computer graphics. Appendix D gives some illustrations of current use. With few exceptions, most use of computer graphics on campus has been in conjunction with research projects due to the expense involved.

Bork (1977) outlines the technical requirements for an effective graphic system for instruction, and, looking at the potential of the videodisc at the 1975 conference cited previously, he states:

> Although the developers of videodisc systems have thought primarily of using the videodisc for bringing movies into the home, such videodiscs, used in stand-alone systems, could have a combination of video sequences, audio sequences, slides, and computer code, all on the same inexpensive disc. Thus, a videodisc might hold a complete elaborate teaching dialog that the student employs at a stand-alone display, complete with slides, video sequences, and the necessary computer code. Or, it might contain the code for a full language, such as APL, along with a full set of materials, including video and slides, for learning that language. Thus, the videodisc would allow a full multimedia approach, combining the computer with other media.

> Finally, I want to state strongly my belief that meetings such as the current one are absolutely essential. Educational computer use is still, I believe, in a very early stage. We must look very carefully into the future, seeing the technological possibilities and trying to mold developments in directions conducive to use in learning environments. Often, pedagogical uses of technological devices have followed the technology; for effective educational use, this is the wrong order. It is important to examine desirable futures from the standpoint of improving learning environments and to influence the development of the technology to create these environments. I am particularly suspicious of arguments from technology, arguments which go along the lines of 'I have a very powerful piece of hardware,' or 'I have a very powerful software idea.' The sensible approach is to start from actual learning and teaching problems; these then should influence the hardware, languages, and computer techniques. (Bork, 1977)

Rensselaer Polytechnic Institute (RPI) has made a major investment in interactive computer graphics in engineering education. Wozny (1978) argues that:

> The real key to computer graphics is giving students enough time on the machine. The computer is nothing more than a dynamic extension of their textbook. Just as students generally require several readings before fully understanding a concept, they should be accorded similar access privileges to a computer. An effective facility must be large enough to handle such a demand.
>
> Computer graphics is effective in engineering education because it emphasizes intuition rather than exact calculations. For years, engineering students used computers simply to get answers expressed to 10 decimal places. In order to understand the underlying relationships, the student generally had to print a number of solutions during one computer run and then try to interpret the tables of numbers or the crude plots from the line printer. Computer graphics overcomes both of these shortcomings because: (1) an interactive system must provide fast turnaround by definition; and (2) its drawing and plotting capability is of high quality. Thus, graphics gives a student immediate reinforcement in a natural conversational graphic mode. Refresh graphics adds the capability of animation. The pedagogical significance of changing with a light pen the location of a single charged particle in an electric field with other charged particles, and watching all the field lines move as if they were rubber bands cannot be overstated! The

pedagogical advantages of computer graphics in perspective are:

- visualization (one picture is worth a...)
- animation (motion)
- interactiveness (what if?)
- intuition (instead of exact calculations)

As stated earlier, the trend in industrial design is toward increased use of computer graphics. Several industries have documented large savings when graphics is used. Graphics offers the design engineer the ability to interact, evaluate, and modify designs directly in the graphics mode. In certain areas where the product is well understood, designs bypass the experimental verification stage entirely and go directly into production! In effect, the computer solution via graphics becomes a pseudo-experimental verification.

Industrial advantages for using graphics are:

- eliminates expensive experimentation
- reduces time between design and production
- provides required human intervention in complex designs
- reduces engineering design time thru human/computer optimization. (Wozny, 1978)

The article cited above also describes the use of imported software in electronic circuit analysis, finite element structural analysis, digital filter design, integrated mechanisms, and multivariable systems design. The use rather than the coding of these complex programs is stressed. Some engineering educators place so much emphasis on analysis and coding that students often are deprived of the opportunity to use a completed package in a design mode. The RPI facility also supports development work on new programs.

The need to develop facilities with similar purposes at each engineering college is a pressing issue in engineering education today. The creation of a national interest group or association, perhaps within the American Society for Engineering Education (ASEE), would be a beginning step. However, at least a dozen prototype facilities should be funded throughout the nation in the next one to three years to serve as organizational and operational models, as clearinghouses for vendors and educators, and as centers for the creation of outreach materials aimed at informing educators within a given discipline or region. The task is too large and important not to design a dispersed support system for both educators and administators to encourage the rapid, meaningful development of interactive graphics and computing in engineering education.

Goals for Computing

Unfortunately, the introduction of computing is highly fragmented in most colleges, and a student's experience depends largely on the particular instructors contacted. The engineering student's exposure to subject matter is highly structured; the curricula is the product of much local faculty discussion and is carefully reviewed by external accreditors. But, the role of computing rarely receives this attention, despite its impact on student learning. Computing is not neglected today, just rarely coordinated.

Faculty profitably could spend more time discussing the curricula. To stimulate a fresh look, Lykos (1975) encouraged faculty of the Illinois Institute of Technology to use M. F. Rubinstein's book, Patterns of Problem Solving (Prentice-Hall, 1975), as a point of departure. Roles for computing then could be put into the general framework of problem solving. The participating faculty engaged in a computer-based laboratory which used a modern simulation language, GASP-IV (Pritsker, 1974), to accommodate the modeling of discrete state, continuous state, and hybrid systems.

Some examples of instructional computing today may be found in these references: Blum, et al., 1971; CONDUIT, 1977; and Zinn, 1980. The U.S. Naval Academy also should be cited as an institution which has made an intensive effort to employ the computer for instruction. Adams and Rogers (1975) review the efforts made in Annapolis in engineering education. Some recent work on computer-augmented video systems for instruction at the Naval Academy was published by Pollack (1978) and Prestia (1978).

Research Applications

No attempt will be made to cite the countless applications which computing has today in engineering research at universities. It is a rare graduate student who does not employ the computer in some fashion in research. Computer movies, cited earlier, may be an output that could be transferred readily to instruction, and, of course, ideas from research are carried by the professor to the classroom.

University-based researchers probably will face a new set of facility problems in the coming decade. Faculty demands to decentralize instructional computing will divert university funds from the central computing facility. Therefore, few universities will have the funds necessary to upgrade the central facility so that local computers might keep abreast of the power made possible by inexpensive microelectronics. The local administrative goal is more likely to be the maintenance of existing central computing services at a lower cost in order to permit funding of decentralized instructional facilities. The net effect probably will be to stagnate the "upper end" of the computing power available to many university researchers.

Chemists have recognized the problem outlined above already, and, with the support of the Department of Energy (DOE) and NSF, have created a National Center for Computation in Chemistry at a DOE facility in Berkeley. Approximately $6 million was invested over a three-year period in this facility which is built around a CAC 7600. Background information about the events which led to this federal investment in chemistry research may be found in Bigeleisen, et al. (1975) and Gilbert, et al. (1974). This facility is now in a phasing-down stage and may cease operations in the near future. On the other hand, the National Center for Atmospheric research in Boulder, Colorado, successfully operates a CRAY-1 for university and resident staff. Clearly, engineering research could benefit from a few regional centers as well. Each should operate very large-scale, user-oriented computing facilities, emphasizing a specific engineering discipline. The National Academy of Engineering should undertake a feasibility study to provide specific direction.

Impediments

Many of the past impediments to computing in education are traceable to the relatively high cost of hardware; therefore, most universities want to maximize utilization of a central facility. Denk (1976) reviews current practices at universities under five support categories: technical and systems; materials; personnel; faculty training; and availability, both economic and administrative. The age of "Big Blue," on which Denk reflects, soon will be yielding to decentralization that will bring a new set of issues. At the policy level, some concern is expressed about the lack of government programs and policies regarding computing.

> Due to major investments made several decades ago, the U.S. is the worldwide leader in computer technology. However, due to our laissez-faire approach to the support of technological innovation, other nations are now challenging that position. They are systematically investing large sums of money in computer research and are restructuring their educational systems to emphasize computing so they may exploit the full potential of computers in all segments of their societies.
>
> Some feel that our current national policy, or the lack of one, will greatly affect our Nation's future level of productivity and our world position in science and technology for many years to come. Many feel that we must undertake an urgent, comprehensive review of our national policy toward technological innovation and with it our policy toward academic research, development, and instruction in the use of computers. (Molnar, 1977)

IV.
HUMAN AND ECONOMIC IMPEDIMENTS

The organizational and environmental impediments to more rapid use of educational technology (ET) must be recognized. Broadly categorized, these impediments are of two kinds: limited human resources and limited economic resources.

Fourth Revolution Delayed: On Campus

Any frontal attack aimed at increasing capital investment in ET and reducing operating costs by replacing teachers is doomed to failure in higher education. Faculty involvement in institutional governance is erratic, a product of a highly decentralized community. Taken as a whole, it would be a rare university that would opt for large-scale adoption of ET. In fact, university budgeting procedures generally preclude the economic trade off, because all capital goods are expensed the year of purchase. The goal of improving education at a reasonable cost, or of improving productivity at the course level (as described by Willey, Appendix B), is not only politically safer to advocate, but also it is the wisest approach to take, given the lack of persuasiveness of ET to date. In our public school systems, upon which taxpayers have a rather direct impact, thousands of teachers did not return to work for the 1978, 1979, and 1980 school years, and at least a half-million students were out of school for awhile in Philadelphia, Boston, Chicago, Cleveland, New Orleans, Seattle, and elsewhere. The disputes between school boards and teachers seemed unusually angry. Rhetoric flourished; solutions did not.

> In the post-Sputnik era, taxpayer contributions to education have doubled, tripled, quadrupled, while test scores of high school graduates suggest we are turning out products with an intellectual capacity somewhere between animal and vegetable. (Buchanan, 1978)

This is not a good environment for innovation, however desirable we consider such a goal.

Affordable instructional technology is now being produced for direct purchase by the learner. Hand-held calculators are an excellent example. The value of the device is so apparent that essentially every engineering student owns one. The half-inch videocassette machines, videodiscs, and personal computers are being produced today by manufacturers in an attempt to create a consumer market in addition to an institutional market. Speak and Spell is an exciting new $50 learning aid from TI (Texas Instruments) that teaches children how to spell by pronouncing each word, then interactively grading and scoring the learner. It is built around a voice synthesizer on a single chip, a technology that will spawn a flood of new TI (Texas Instruments) products that can talk (Business Week, 1978).

Commercial mass marketing directly to the learner has not been seriously considered an alternative for ET before. All previous studies have assumed an introduction through institutional budgets and classical curricula (e.g., Tickton, 1970; PSAC, 1967; Carnegie Commission, 1972; and Bugliarello, 1974). The pattern described is circular: the high cost of software; the lack of effective national distribution; and, hence, little development of software.

Special purpose devices with fixed algorithms, like Speak and Spell, are an attractive alternative, if the special purposes that are developed happen to include the items you wish to learn. A device like the read-only videodisc in its present configuration, however, is a good example of how a technology can easily be designed for the marketplace in such a way as to preclude wide-scale development of courseware in higher education. The technology of making a "master" clearly must be modified, if wide-scale development of instructional materials is to proceed. Nevertheless, ten years from now, a review of current ET activities surely will include many more examples because the hardware is becoming much more affordable and a new generation of young instructors will have an impact.

The focus away from hardware, which may come inexpensively in great variety, and toward the instructional goals for ET will surely benefit all. Discipline research is now accepted by engineering faculty as a way of life, a never ending process, because external funding has made wide-scale participation possible. Faculty time, graduate assistants, support staff, as well as specialized, ever-changing hardware are annually allocated in peer-reviewed, national competition. Efficiency is rarely an issue; instead, the quality of the endeavor is judged for its intellectual and, in engineering at least, its practical value. There is great diversity.

The external stimuli for this revolution in campus activity is not a secret; the revolution could not have been wrought by formula funding, by a single agency, or at a small fraction of the cost that has been incurred. While there are key national centers for certain specialized facilities and "think tanks," research policy-makers have generally sought wide participation and have found talent throughout the nation. Professional meetings, publications, and awards support local efforts.

The integration of ET in universities to improve education should, like discipline research, be process-oriented, not product-oriented; should be a sustained effort, not the product of occasional Requests for Proposals; and should involve many more talented people than it does today in work ranging from immediate local applications to basic research in artificial intelligence. Compelling demonstrations of instructional technology will become commonplace once the level of human effort reaches a certain threshold and the hardware is distributed widely (Lipson, 1977).

Yet, more external stimuli are essential. Most state universities are embedded in a bureaucracy which bears a great resemblance to social service programs. More often than not, innovation is actively discouraged when there are negative budget incentives for increased productivity. Private universities are constrained by tight budgets and, of course, by federal regulations which pervade all of higher education. Caretaker styles of university administration prosper today. Therefore, foundations and agencies that want to encourage the appropriate use of ET should pay careful attention to organizational situations. Indeed, the use of not-for-profit corporations, perhaps with close university ties, should be explored.

Rothenberg and Morgan (1975) report on two case studies of innovation in the educational service sector: "Sesame Street" and the Children's Television Workshop; and Patrick Suppes' computer-aided instruction (CAI) work in the Institute of Mathematical Studies in Social Sciences at Stanford as well as in the Computer Curriculum Corporation. The studies provide details on the nature of the problem and the history of the innovation, the subsector or environment, the initiating unit, the innovation, techniques affecting adoption, the adopters, the users, and the impact of the innovation. In both of these successful ET efforts, the need arose for a new organizational structure.

Engineering Education: Off Campus

Fortunately, most outreach programs are so new that bureaucratic constraints are far less inhibiting than in other areas of university endeavor. The cardinal rule is pay-as-you-go, i.e., self-sufficiency. New enterprises often display considerable entrepreneurial spirit in carrying out their missions. The client for off-campus extensions of graduate education and continuing education appears willing to pay for services delivered. Similarly, foreign programs have well developed funding sources. The problem areas which require continual subsidy include programs aimed at junior colleges, at high schools, and at promoting public understanding of technology.

Resource sharing between colleges in technology-based outreach programs should be encouraged. Consortia of engineering schools such as the Association for Media-Based Continuing Education for Engineers (AMCEE) may prove effective agents of campus change as well as suppliers of educational services to practicing engineers at their job sites. Can the faculty resources be effectively pooled through the

AMCEE organization and the use of modern communications technologies? If so, the interaction of engineering faculty with engineers and managers who engage in these graduate and continuing educational programs could provide an operational link between practioners and educators that has long been missing.

V.
SUGGESTIONS FOR IMPROVEMENTS

This concluding section is divided into two parts. The first, Critical Issues, deals with a set of general concerns and institutional issues. To the extent that the three issues identified are judged to be valid, a set of criteria to evaluate specific educational technology (ET) programs and initiatives might be formulated. Clearly, no single set of activities will eliminate the overall problems, but each proposed program could be assessed by the extent to which it trains and rewards faculty, improves the quality and dissemination of materials or resource sharing, and encourages non-bureaucratic responses. The final section summarizes the suggestions for improvement which were integrated into the text.

Critical Issues

James D. Koerner provides a valuable insight into the immediate future of ET. From 1970 to 1976, Koerner served as manager for the Technology in Education program of the Alfred P. Sloan Foundation. During that period, the foundation made about eighty grants totaling approximately $8 million. He is optimistic, noting that:

> Communications technologies are steadily infiltrating the instructional programs of colleges and universities and [experience] suggests that they will do so in the future at an accelerated pace. The question is simply one of how long it will take for technology to become an intimate and integral part of the higher education scene....To speed the development process, certain steps, implicit in the foregoing discussion, need to be taken in higher education. (Koerner, 1977)

Training and Rewarding Faculty

Like all other technology, ET requires key human resources for implementation. The appropriate adoption of ET is seriously hindered by a historical lack of a broad-scale, sustained effort to enlarge the number of talented individuals working with media.

> One essential step for the future is for colleges and universities to find ways of multiplying manyfold the number of faculty members experienced in and committed to development work. That is an expensive and time-consuming step, and the difficulty of taking it is suggested by the fact that not a single recognized center now exists anywhere in the country to which interested faculty members from other institutions could be sent for what might be called basic training in educational technology. (Koerner, 1977)

Academic faculty lacking personal exposure to effective applications of ET are often less than enthusiastic about non-traditional instruction methods. To the extent that this is a product of natural conservatism, then engineering faculty react no differently than do other faculty. However, to the extent that issues associated with the design and operation of hardware configurations and systems are involved, then engineering faculty have a natural advantage over other disciplines. Furthermore, engineering faculty have shown more willingness to take risks in discipline-oriented research than their colleagues in the sciences. Stimulation of meaningful interests in pedagogical issues is essential.

Improving Materials/Resource Sharing

Many believe that improving the quality and dissemination of materials, i.e., resource sharing, is the most important problem. Individuals working alone rarely have the tenacity or resources to sustain the effort necessary to produce high-quality course materials in modern media. Small instructional teams, including talented graduate students, are more likely to succeed.

> If means could be found in the future to permit the sustained development of the teaching materials, the "software," of educational technology, one of the principal problems of the field might be solved. It is trite but true to say that the hardware of educational technology has always outrun the software; the hardware continues to do so today....A great deal of new software has been developed..., but most of it represents no more than a first-try effort by the scholars involved, with all of the imperfections that first-try efforts in education normally have.

> Not widely appreciated is the fact that the transformation of instructional material from the conventional format of book and blackboard to one in which the substance is conveyed to unseen students by a variety of machines is an exceedingly demanding, frustrating, and time-consuming task. Even determining the kind of topics that lend themselves best to presentation by each kind of device is a problem requiring a good deal of experimentation, and when solved may be successful with only certain kinds of students. Once developed, a software program needs, but rarely gets, an extended series of trials and tests.
>
> Although the barriers to the extensive sharing of materials are several, the main one is clear: the first requirement of adoption of technology-based software is that there be something worth adopting; not many first-round efforts at developing software are. Software must therefore become a great deal better than most of it now is before it will have a chance of being actually used very far beyond home base. To that end, foundations and other organizations that support development work might now consider financing fewer projects for longer periods of time. Ten years is not too long to support a major project to produce materials that have been tested, revised, retested, and again revised, and to make a clear demonstration of their effectiveness. If long-term support for large projects is not forthcoming, educational technology will continue to develop in the haphazard and redundant fashion of the past. (ibid.)

Far more attention should be paid to understanding the reactions of students to media. Creating environments for acceptance of ET by campus students is more complex than it may appear. Systematic exploration of the factors affecting student attitudes should be encouraged, and the results of these studies periodically summarized for educators. Effective ET will surely have to combine the utilization of higher quality courseware with more knowledge about how to solicit favorable student attitudes.

Mission-oriented organizations that involve subgroups of faculty from several universities offer the potential of sustained external guidance and stimulus. Consortia such as the Association for Media-Based Continuing Education for Engineers (AMCEE) provide assurance of continuity of effort regardless of changes in personnel at individual institutions. Similar resource-sharing organizations might be created to develop computer-aided design (CAD) instructional materials for engineers, to create media for case studies of engineering practice, to provide instructional films in professional ethics, and to carry out mediated instructional programs overseas in conjunction with foreign universities.

Encouraging Non-Bureaucratic Responses

Few, if any, educators expect to become rich in their work. Financial incentives for faculty are not well developed in ET, and care needs to be taken to ensure that a reasonable marketplace is created, one which recognizes individual and group efforts. Perhaps equally important to faculty are professional incentives and recognition. A conscious effort to enhance the professional esteem of ET activities should be a part of all programs.

Faculty generally perceive the university press as a prestigious institution closely tied to a commitment of scholarship. Chester Kerr, Director of the Yale University Press, is quoted in a lighthearted moment as saying, "We publish the smallest editions at the greatest cost, and on these we place the highest prices, and then we try to market them to people who can least afford them. This is madness!"

Might it be possible to raise the level of faculty commitment to ET by creating a selected number of modern ET "presses"? Rather than monographs, these media-based publishers could specialize in the production of high-quality courseware, integrating creative university staffs in video and computation with master teachers and their cohorts. Librarians could be trained to maintain central facilities on each campus to expose students and faculty to outstanding examples of ET. In time, these modern university "presses" could provide the institutionalization and prestige which today's ET efforts lack. Equally important, an entrepreneurial spirit could be wed early to what could become authoritative outlets for creative ET work. Endowments creating these new organizations would help assure not only initial working capital but also needed autonomy.

Suggested Actions

A number of suggestions are included in the text in conjunction with the discussion of a particular application of a technology. Table 7 summarizes these recommended actions together with one new organizational concept which would involve all aspects of ET in practice. Table 7 is an array of both on-campus and off-campus applications which uses the vertical columns for specific applications and horizontal rows for specific technologies/organizations. The divisions involving "new" and "existing" are somewhat arbitrary but are included to help differentiate the more research-oriented tasks from those which could be undertaken as developmental implementations.

Since the primary purpose of this report is to provide a critical evaluation of the ET literature with respect to its applications to engineering education. The authors' suggestions as outlined in Table 7 are made throughout the report and are summarized here in the hope that they will serve as stimuli for thoughtful consideration and, perhaps, even action. The principle suggestions, listed in order of priority, are:

TABLE 7
SUMMARY OF SUGGESTED ACTIONS

		Existing Applications		New Applications	
		On Campus	Off Campus	On Campus	Off Campus
Existing Technology	Existing Organization	Build pool of knowledgeable educators using ET for local course improvement; studies of productivity and student attitude toward ET. (pp. 7; 91-93; 108-114)	Extend high quality graduate and continuing education nationwide through AMCEE. (pp. 59-62)		Increase use of personal ET in programs for minority students in grades 9-12. (pp. 9; 46-47; 65-66; 97-98)
	New Organization			Create prestigious centers of ET, "university videopresses," as new models for production of high quality course materials. (pp. 8-9; 56; 115) Encourage consortia to produce media for case studies instruction in engineering design and professional ethics. (pp. 11-12; 43-45) Fund twelve prototype centers for instruction in computer-aided design and manufacture. (pp. 7-8; 100-104)	
New Technology	Existing Organization	Fund an independent study of modern instrument and equipment problems of colleges of engineering (pp. 10-11; 98-99)	Test use of satellites and modern communication technology in the AMCEE task above. (pp. 9-10; 75-81; 110-111)	Initiate a forecast of the issues and public policies related to new consumer–oriented ET. (p. 11)	Undertake the negotiations and feasibility studies to make cooperative programs of postgraduate engineering education available to foreign nations by satellite. (pp. 10; 69; 116)
	New Organization	Undertake feasibility study for the creation of several regional centers of computation in engineering research. (pp. 13; 105-106)		Design new agency programs to encourage transfer of knowledge and courseware in ET. (pp. 11; 97)	

1. The number of talented individuals working with ET needs to be enlarged greatly in order to increase the impact of powerful new delivery systems.

- Government agencies should design funding programs which encourage broad-scale, diversified development and testing of ET courseware in various media at the local course level. Although some basic instructional research in artificial intelligence and other, similar areas should be funded, major support should be given to improving local courses and to productivity studies. The purpose of these programs would be to involve many more faculty, nationwide, in meaningful ET activities.

2. The unique learning experiences provided by combining interactive computing with individual graphic displays, although rarely practiced today, should be widely available to engineering students. Courseware in computer-aided design and simulations of computer-aided manufacturing need to be created for all engineering disciplines. The colleges that pioneer in these endeavors will incur equipment costs and software development expenses. (Although the cost of equipment is currently high, it is likely to decline in the future.) To provide incentives for the immediate initiation of such programs, it may be necessary to subsidize a first generation of facilities. Follow-up federal programs also may be necessary several years later to ensure widespread availability of computer graphics equipment.

- At least twelve prototype computer graphics centers should be funded in the next two years at selected engineering colleges. These centers would serve as regional models for the organization and operation of interdisciplinary facilities, as clearinghouses for vendors and educators, and as developers of outreach materials for engineering educators nationwide. External funding of these pioneering centers might require one-third to one-quarter local matching funds. A second round of facility grants to ensure the general availability of computer graphic equipment might involve as much as a 50 percent match by colleges and universities.

3. Videopublishing gives the university a distinctly new opportunity to serve the practicing professional. New organizations are needed to undertake this task. These new university "videopresses" would bring together the human resources: master teachers; manuscript editors; video production staffs; and computer software experts. All of the marketing and distribution skills of the traditional publishing house are necessary. Early efforts in videopublishing should provide visible models which combine both the scholarly prestige and the entrepreneurial spirit of the traditional university presses.

- Several university videopresses should be endowed at universities having both a strong commitment to continuing education of professionals and the media expertise to set high standards of quality. These new enterprises would provide a creative outlet for faculty everywhere and encourage the development of modern instructional programs under the guidance of skilled staff.

4. Modern communications technologies one day may make extensive resource sharing a reality in higher education. Early efforts should focus on non-threatening domains in order to elicit maximum faculty cooperation. The AMCEE consortium brings together the resources of 22 universities which have major investments in regional ITV systems designed to provide both graduate and continuing education programs to engineers at their job sites. New communications technologies could be introduced into universities most effectively through mission-oriented activities such as those proposed by AMCEE.

- An operational plan to test the cost effectiveness of communications satellites should be funded to provide engineers with the following educational services at their job sites: national delivery of graduate credit courses in a coordinated program initially involving 10 AMCEE universities; delivery of continuing education short courses; and teleconferencing between originating sites to provide for direct faculty exchanges, special seminars, and technical meetings. Studies should be undertaken to involve ethnic minority colleges of engineering in activities of their choosing.

5. Technology exchange with foreign nations wishing to provide opportunities for engineering postgraduate study in the United States could be accomplished by means of satellite interconnections and cooperative arrangements between AMCEE colleges and foreign universities.

If satellites are used to extend U.S. engineering postgraduate education overseas, the keyword is cooperation. The details of the operations need to be negotiated with foreign educators and officials to ensure that the organizational configuration, the academic programs offered, and the assignment of academic responsibilities are distributed in a mutually agreed upon manner. Fuller (1978) argues that higher education might well be a major U.S. export industry in the future because America enjoys the opportunity of a lower real economic cost due to its existing institutions and its leadership in communications and scientific research. The preliminary studies conducted by the Association for Media-Based Continuing Education for Engineers (AMCEE) show such operations to be technically feasible. The advantages of offering high-quality educational opportunities in the homeland of the student warrant the investment necessary to employ modern communications technology as the backbone of the system.

- Post-graduate study programs offered by U.S. engineering colleges might be transmitted overseas via satellite. The potential advantages of high-quality educational opportunities available in the homeland of the student may warrant the investment necessary to employ modern communications technology.

6. Campus instructional laboratories are rarely equipped with the powerful new measurement instruments now found in industrial practice. University equipment budgets have not kept pace with the emergence of modern devices, and this problem is becoming more acute each year.

- An in-depth study of the equipment problems of colleges of engineering should be undertaken, perhaps by an industrial team sponsored by the National Research Council. Recommendations might include government incentives to industry, as well as emergency programs to overcome what has become a massive problem of hardware acquisition.

7. The decentralization of instructional computing appears inevitable. This transition will bring many new problems in funding and operations to campuses; it also will bring unparalleled opportunities to integrate computing into the students' experience.

- Federal agencies should design a number of new programs to expedite the transition to decentralized computing. These diverse efforts might include sponsorship of the following: consumers' unions to evaluate machines and courseware; visiting lectureships; workshops and summer institutes; and media-based, packaged, short courses for in-service training of teachers.

8. The case study method of instruction is gaining popularity in engineering as an effective way of bringing practical design problems into the undergraduate curriculum. Television or films have been shown to add realism and a stimulating emotional dimension to an otherwise highly abstract instructional program. However, very little media is now in use in engineering instruction.

- Foundations should explore the creation of working consortia or nonprofit organizations to produce high quality films and videotapes in support of case study instruction, especially in engineering design and in professional ethics.

9. ET has made possible engineering-related programs for students in both rural and inner-city high schools. Films produced by industry that give an orientation to engineering, introductory computer courses delivered by videotape, hand-held calculators, and personal computers all have been employed successfully in gaining the interest of ethnic minority students. More effective and universal programs now might be planned based on the experience gained to date.

- The use of ET in attracting, motivating, and preparing ethnic minority students and others who are educationally disadvantaged in grades 9 through 12 should be extended. A few university-based centers could supply materials and information to the many programs which are now sponsored by businessmen and educators regionally.

10. Decentralization of instructional computing may preclude the upgrading of university central computing facilities. University-based researchers may find it difficult to participate in the powerful advances being made in super computers.

- The National Academy of Engineering (NAE) should sponsor a feasibility study on the creation of several regional computation centers for engineering research.

11. The rush to create a consumers' market in ET will probably have a profound impact on learners of all ages. Yet, this literature survey uncovered no systematic study of the implications of this development, nor were articles found that address the issue of how educators and schools may react.

- The NAE should update its 1974 study on issues and public policies in ET in the light of current trends and forecasts in hardware delivery systems.

REFERENCES

Adams, J.A. and Rogers, D.F., "Computers," Ch. 7 in Grayson, L.P. and Biedenbach, J.M., Teaching Aids in the College Classroom, American Society for Engineering Education, Washington (1975).

Adams, J.A., "A Big Leap Forward for Computer Based Learning in the U.K.," Office of Naval Research, European Scientific, Notes, ONBR London, ESN 32-7 (July 31, 1978).

Alden, J.D., "Opportunities for Engineering Graduates," Engineering Education, 64, pp. 493-497 (April, 1974).

Alterman, D.L., Appel, L.R., and Murphy, R.T., "PLATO and TICCIT: An Evaluation of CAI in the Community College," Educational Technology, XVIII, in 4, pp. 40-45; plus responses from producers, pp. 45-46 (April, 1978).

Anderson, R.M., "Evaluation of Graduate Engineering Education by Television at Purdue University," Proceedings of IEEE, 66, No. 8, pp. 918-926 (August, 1978).

Baldwin, L.V., Collias, A.J., Davis, C.M., and Schmaling, G., Workshop on Continuing Education for Engineers at Midcareer, Colorado State University, Fort Collins, p. VIII-3 (August, 1974).

Baldwin, L.V. and Davis, P.N., "Videobased Graduate Education for Part-Time Students Off-Campus," Scienza & Tecnica '75, Milano, Italy (1975).

Barile, R.G., Hauze, R.N., and Wankat, P.C., "TV Taping of Laboratory Oral Reports," Proceedings of ASEE/IEEE Frontiers in Education Conference (1977), United Engineering Center, New York (1974).

Bartolini, R.A., Bell, A.E., Flory, R.E., Lurie, M., and Spong, F.W., "Optical Disk Systems Emerge," IEEE Spectrum, 15, No. 8, pp. 20-28 (August, 1978).

Bell, J.M. and Brenchley, D.L., "Engineering Case Study Approach for Studying Community Problems," Preprint from Event 2560, ASEE Annual Meeting, Texas Technical University, Lubbock (June, 1972).

Bigeleisen, J. (Chairman), "The Proposed National Resource for Computation in Chemistry: A User-Oriented Facility," Office of Chemistry and Chemical Technology, National Research Council, Washington, D.C. (1975).

Bloom, B.S. (ed.), *Taxonomy of Educational Objectives: Handbook 1: The Cognitive Domain*, Wiley, New York (1956).

Blum, R. (ed.), *Conference Proceedings: Computers in Undergraduate Science Education*, Commission on College Physics, College Park, Maryland (1971).

Bork, A., "Learning, Computers, and Pictures," *Technological Horizons in Education Journal*, *1*, No. 5, pp. 6-13 (November, 1974).

Bork A., "Learning Through Graphics," in Sec. 5, Seidel, R.J. and Rubin, M., *Computers and Communication: Implications for Education*, Academic Press, Inc., New York (1977).

Bowen, C.G., "The University as Videopublisher of Last Resort," *Cable Television and the University*, EDUCOM, Princeton (1974).

Braun, L., "Microcomputers and Video Disc Systems: Magic Lamps for Educators?" Report to N.I.E., National Coordinating Center for Curriculum Development, State University of New York at Stony Brook (1977).

Britton, C.C. and Schweizer, H.H., "Freshman Engineering at Colorado State," *Engineering Education*, *65*, No. 2, pp. 162-165 (November, 1974).

Brumley, W., Department of Mathematics, Colorado State University; personal communication (September, 1978).

Buchanan, P., "New Hampshires' Populist of the Right," nationally syndicated column, "The Dividing Line," Chicago Tribune-N.Y. Times Syndicate, Inc. (September, 1978).

Buchnell, D.D. and Allen, D.W. (eds.), *The Computer in American Education*, John Wiley & Sons, Inc., New York (1967).

Bugliarello, G., *et al*., "Issues and Public Policies in Educational Technology," Report of N.A.E. Advisory Committee, Lexington Books, D. C. Heath & Co., Lexington, Massachusetts (1974).

Bulkeley, P.Z., (ed.), "Authentic Involvement in Interdisciplinary Design," *Proceedings of the Third Conference on Engineering Design Education*, Carnegie Institute of Technology, Pittsburgh, Pennsylvania (June, 1965).

Business Week, "Texas Instruments Shows U.S. Business How to Survive in the 1980's," Number 2552, pp. 66-92 (September 18, 1978).

Carnegie Commission on Higher Education, *The Fourth Revolution: Instructional Technology in Higher Education*, McGraw-Hill, New York (1972).

Carpenter, C.R., "Instructional Television Research," Report No. 2, Pennsylvania State University, University Park (1958).

Chemical and Engineering News, *53*, "Engineering Society Tackles Age Bias," p. 7 (September 22, 1975).

Cohen, K.C. (ed.), "Proceedings of the First National Workshop on Energy Efficiency Education Through Technology Transfer," Division of Power Systems, U.S. Department of Energy (December, 1977). (Available from the Editor, Room 9-369, Massachusetts Institute of Technology).

Cohen, K.C., "Project PROCEED: A Traditional and Innovative Approach to Continuing Engineering Education," Preprint, ASEE Annual Meeting, University of British Columbia, Vancouver, Canada (June, 1978).

Committee on Satellite Communications of the Space Applications Board, "Federal Research and Development for Satellite Communications," National Research Council, National Academy of Sciences, Washington, D.C. (1977).

CONDUIT, Abstracts and Reviews of Tested Curriculum Materials, University of Iowa, Iowa City (Spring, 1977).

CONDUIT, Computers in Undergraduate Teaching: State of the Art Report for Selected Disciplines, University of Iowa, Iowa City (1977).

Control Data Education Co., Courseware Catalog, Educational Services of Control Data Corporation, Minneapolis-St. Paul (January, 1978).

Davis, C.M. and Gunderson, N.O., "Description of a Successful Joint Venture in ITV-Based Continuing Education," Workshop on Continuing Education for Engineers at Midcareer, Colorado State University, Fort Collins (August, 1974).

Deardorff, J.W., "A Numerical Study of Three-Dimensional Turbulent Channel Flow at Large Reynolds Numbers," Journal of Fluid Mechanics, 41, pp. 453-480 (1970).

Denk, J.R., "Instructional Computing Support for Higher Education," Conference of Computer Applications in Instruction for College and University Executives, IBM, San Jose, Calif. (July 7-9, 1976).

Diehl, M.H., "Use of Hand-Held Calculator in Algebra I Classes in Chicago Public Schools: June 1977 - June 1978," National Coordinating Center for Curriculum Development, State University of New York at Stony Brook (September, 1978).

Down, K.S., "The Stanford Instructional TV Network: A Survey of Its Students," Engineering Education, 66, pp. 762-763 (April, 1976).

Dwyer, T. and Sweer, L., "The Cybernetic Crayon: A Low Cost Approach to Human Interaction with Color Graphics," Byte, 1, No. 12 (December, 1976).

Educational Policy Research Center, Instructional Television: A Comparative Study of Satellite and Other Delivery Systems, Syracuse Research Corporation, Syracuse, New York (November, 1976).

Eide, A., "Educational Television," paper presented at ASEE Annual Meeting (1971).

Eide, A., "Instructional Modules with Cassette Television," paper presented at ASEE Annual Meeting (1974).

Feinstein, W., Bell Labs, 600 Mountain Avenue, Office No. 3B-337, Murray Hill, New Jersey, personal communication (September, 1978).

Flanagan, D. (ed.), Microelectronics, W. H. Freeman & Co., San Francisco (September, 1977).

Florman, S., The Existential Pleasures of Engineering, St. Martins Press, Inc., New York (1975).

Fuller, A.B., "The Educationalization of America," The Chronicile of Higher Education, XVIII, No. 8, p. 40 (October 28, 1978).

Gibbons, J.F., Kincheloe, W.R., and Down, K.S., "Tutored Videotape Instruction: A New Use of Electronics Media in Education," Science, 195, pp. 1,139-41,146 (March, 1977).

Gilbert, T.L., Lykos, P., and Wahl, A.C. (eds.), "Planning a National Center for Large Scale Computation in Chemistry Research," Argonne National Laboratory and Argonne Universities Association, ANL-8085 (June, 1974).

Haggerty, P.E., "Individualized Instruction and Productivity in Education," Ch. 1 in Grayson, L.P. and Biedenbach, J.S. (eds.), *Individualized Instruction in Engineering Education*, ASEE Monogram Series (May, 1974).

Hamblen, J.W., "Academic and Administrative Computing: Where Are We?" *EDUCOM Bulletin*, *12*, 1, pp. 2-7 (Spring, 1977).

Hamblen, J.W., Department of Computer Science, University of Missouri-Rolla; personal communication (September 29, 1978).

Hamblen, J.W. and Landis, C.P., (eds.), *The Fourth Inventory of Computers in Higher Education*, EDUCOM Series in Computing and Telecommunications in Higher Education, No. 4, Princeton (1980).

Hamblin, W.H., "Dilemmas in Legal Ethics," *Catalog of Videotape Programs*, Consortium for Professional Education, American Bar Association, 115 East 60th St., Chicago, Illinois 60637 (July, 1978).

Hartley, J., "Programmed Instruction 1954-74: A Review," *Programmed Learning and Educational Technology*, *11*, No. 6, (November, 1974).

Hawkridge, D.G., "Media Taxonomies and Media Selection," Milton Keynes, England (mimeo, not dated).

Hawkridge, D.G., "Problems in Implementing Computer Managed Learning," *British Journal of Educational Technology*, *1*, No. 5, pp. 31-43 (January, 1976).

Hayman, R.W. and Lord, W., "A Technology-Based Educational System Using Computer Management," *Educational Technology*, *XII*, No. 12, pp. 43-52 (December, 1972).

Hayman, R.W. and Levin, H., "Economic Analysis and Historical Summary of Educational Technology Costs," Appendix C of Melmed, A. (ed.), *Productivity and Efficiency in Education*, Federal Council on Science and Technology, Washington, D.C. (1973).

Heuston, D.H., "The Promise and Inevitability of the Videodisc in Education," Report to N.I.E., WICAT, Inc., Orem, Utah (September, 1977).

Holman, J.P., Department of Mechnical Engineering, Southern Methodist University, personal communication (1977).

Holmes, R., Dean of Engineering, General Motors Institute, Flint, Michigan, personal communication (1978).

Hooper, R., "Making Claims for Computers," *International Journal of Mathematics, Education, Science, and Technology*, *5*, pp. 359-368 (1974).

Jamison, D., Suppes, P., and Wells, S., "The Effectiveness of Alternative Instructional Media: A Survey," *Review of Educational Research*, *44*, No. 1, pp. 1-68 (Winter, 1974).

Keller, F.R. and Koen, B.V., "The Personalized System of Instruction: State of the Art 1976," Section 3, University of Texas at Austin (1976).

Kenyon, R., Dean of Engineering, Rochester Institute of Technology, Rochester, New York, personal communication (September, 1978).

Klus, J.P. and Jones, J.A., *Engineers Involved in Continuing Education: A Survey Analysis*, ASEE Monogram, Washington, D.C. (March, 1975).

Koen, B.V., "Teaching Engineering Design by Authentic Design," *Proceedings of Joint Automatic Controls Conference*, Purdue University, West Lafayette, Indiana (1976).

Koerner, J.D., "The Present and the Future in Educational Technology," Alfred P. Sloan Foundation, New York (May, 1977).

Lauer, B.E. (ed.), *THE Catalog*, 4 volumes, 146 Fourteenth St., Boulder, Colorado 80303 (1978).

Lipson, J.I., "Conditions for Progress in Instructional Technology," Sec. 3 in Seidel, R.J. and Rubin, M.L., *Computers and Communications: Implications for Education*, pp. 221-229, Academic Press, Inc., New York (1977).

Loomis, H.H., Jr. and Brandt, H., "Television as a Tool in Engineering Education," *IEEE Transactions on Education*, E6, Issue 2, pp. 101-109 (May, 1973).

Luehrmann, A., "Dartmouth Project COEXIST," Proceedings on Computers in Undergraduates Curricula, Dartmouth College, Hanover, New Hampshire, p. 2 (1971).

Lumsdale, A.A. and Glaser, R., "Teaching Machines and Programmed Learning: A Source Book," Department of Audiovisual Instruction, National Education Association, Washington, D.C. (1960).

Lykos, Peter, "E^3 - Role of Computer," Association for Computing Machinery, *SIGCUE Bulletin*, *9*, No. 1, pp. 28-29 (January, 1975).

Lykos, P., (ed.), *Minicomputers and Large Scale Computations*, American Chemical Society (ACS) Symposium Series No. 57, ACS, Washington, D.C. (1977).

Lykos, P., (ed.), "Proceedings of a Conference on the Use of Media-Based Materials by Professional Societies in Continuing Education," Association for Media-Based Continuing Education for Engineers, Georgia Institute of Technology, Atlanta, Georgia 30332 (October, 1978a).

Lykos, P., (ed.), *Computer Modeling of Matter*, American Chemical Society (ACS) Symposium Series No. 86, ACS, Washington, D.C. (1978b).

Magidson, E.M., "Student Assessment of PLATO: What Students Like and Dislike About CAI," *Educational Technology*, XVIII, No. 8, pp. 15-18 (August, 1978).

Maxwell, L.M., "CSU Educational Media: Part III; Co-Tie - Cooperation Among Colleges," *Technological Horizons in Education Journal*, *5*, No. 3, pp. 36-38 (May/June, 1978).

McCosh, R.B., "Television Assisted Instruction in Accounting," *Journal of Business Education*, *XLV*, No. 7, pp. 274-276 (1970).

McCosh, R.B., personal communication, Colorado State University, Fort Collins (September, 1978).

Melmed, A. (ed.), "Productivity and Efficiency in Education," Federal Council on Science and Technology, Washington, D.C. (1973).

Merrill, M.D. (ed.), *Instructional Design: Readings*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey (1971).

Miller, D.C. and Baldwin, L.V., "Use of Television for Presentations," Ch. 5 in Grayson, L.P. and Biedenbach, J.M. (eds.), *Teaching Aids in the College Classroom*, *ASEE*, Washington, D.C. (1975).

Mitzel, H.E. (ed.), Conference Proceedings: An Examination of the Short-Range Potential of Computer-Managed Instruction, Pennsylvania State University, Report on NIE Grant No. C-74-0091 (November, 1974).

Molnar, A.R., "National Policy Toward Technological Innovation and Academic Computing," National Science Foundation Manuscript, Washington, D.C. (1977).

Morris, A.J., Down, K.S., Munushian, J., McGhie, L.F., Rubenstein, R., and Hike, R.C., "Final Report on Cost Effectiveness of Continuing Engineering Studies by Television," CES Division, American Society of Engineering Education, Washington, D.C. (May, 1974).

Morris, A., et al., "The Return on Investment in Continuing Education of Engineers," Final Report on NSF Grant EPP-75-21587, Genesys Systems, Inc., Palo Alto, Calif. (May, 1978).

National Institute of Education, "Conference on Educational Applications of Satellites," Arlington, Virginia, National Institute of Education, Washington, D.C. (February, 1977).

Neidt, C.O., "Final Report: Project Colorado CO-TIE," Prepared under NSF Grant GY 5305, Colorado State University, Fort Collins (1970).

Neidt, C.O. and Baldwin, L.V., "The Use of Videotape for Teaching In-Plant Graduate Engineering Courses," Adult Education, XX, No. 3, pp. 154-167 (1970).

Oliver, B.M., "The Role of Microelectronics in Instrumentation and Control: Ch. 8, in Flanagan, D. (ed.), Microelectronics, W. H. Freeman & Co., San Francisco (1977).

Papert, S., "A Learning Environment for Children," in Sec. 4, Seidel, R.J. and Rubin, M.L. (eds.), Computers and Communications: Implications for Education, pp. 271-278, Academic Press, Inc., New York (1977).

Pask, G. and Lewis, B., "Teaching Strategies: A Systems Approach," in Unit 9 of The Curriculum: Context, Design and Development, Open University, United Kingdom (1972).

Perlberg, A. and O'Bryant, D.C., "Videotaping and Microteaching Techniques to Improve Engineering Instruction," Engineering Education, 60, pp. 741-744 (March, 1970).

Pettit, J. and Hawkins, W. (eds.), "Final Report: Goals of Engineering Education," Journal of Engineering Education, 369-446 (January 1968).

Pollask, R.A., "Computer Augmented Video Education: An Overview," Proceedings of the Ninth Conference on Computers in Undergraduate Curricula, Library of Congress Card No. 74-10711 (1978).

President's Science Advisory Committee, Committees in Higher Education, U.S. Government Printing Office, Washington D. C. (1967).

Prestia, J.V., "Computer Augmented Video Education in Troublesome areas of Chemistry," Proceedings of the Ninth Conference on Computers in Under-Graduate Curricula, Library of Congress Card No. 74-10700 (1978).

Pritsker, A. and Allen, B., GASP-IV: Simulation Language, John Wiley & Sons, New York (1974).

Rahman, A. and Stillinger, S.H., "Molecular Dynamics Study of Liquid Water," Journal of Chemical Physics, 55, pp. 3,336-3,359 (1971).

Rivers, R.A., "Age Discrimination Patterns in Engineering Employment," in The E/E at Mid-Career - Prospects and Problems, The Institute of Electrical and Electronic Engineers, Inc., Washington, D.C. (1975).

Rogers, J.L., "The Russians Are Learning," Audio-Visual Communication (April, 1974).

Rogers, J.L., "Moving From Broadcast to Videotape in a University-Based Instructional TV Network," Proceedings of ASEE College Industry Education Conference, San Diego (January, 1978), Washington, D.C., 1978.

Rosauer, E.A., "Electron Microscopy via Television," Engineering Education, 60, p. 710 (March, 1970).

Rosenstein, A.B., "Modeling, Analysis, Synthesis, Optimization, and Decision Making in Engineering Curricula," DEP-2-68, Report of Department of Engineering, University of California in Los Angeles (1968).

Rothenberg, D. and Morgan, R.P., "Case Studies of Innovation in the Educational Service Sector," Center for Development Technology, Washington University, St. Louis (July, 1975).

Salloway, N., "Video at MIT: A Progress Report," Center for Advanced Engineering Study, Massachusetts Institute of Technology, Cambridge (May, 1974).

Sanders, H.J., "Continuing Education: The Intensified Effort to Keep Up To Date," Chemical and Engineering News, pp. 18-27, 26-38 (May 13 and 20, 1974).

Schmaling, G.P., "Status of Video Based Graduate Engineering Education in the United States," Workshop on Continuing Education for Engineering at Mid-Career, Colorado State University, Fort Collins, pp. 1-58 (August, 1974).

Schneider, E.W., "Applications of Videodisc Technology to Individualize Instruction," Session 5, in Seidel, R.J. and Rubin, M., Computers and Communications: Implications for Education, pp. 313-326, Academic Press, Inc., New York (1977).

Schramm, W., (ed.), Quality in Instructional Television, The University Press of Hawaii (1972).

Schramm, W., Big Media, Little Media: Tools and Technologies for Instruction, Sage Publications, Inc., Beverly Hills, California (1977).

Science, "Computer Films: Adding an Extra Dimension to Research," 200, pp. 749-752 (May 19, 1978).

Scott, K.E., Peura, R.A., and Demetry, J.S., "The W.P.I. Plan: A Case Study," Ch. 10 in Grayson, L.P. and Biedenbach, J.M. (eds.), Individualized Instruction in Engineering Education, ASEE Monogram Series, Washington, D.C. (May, 1974).

Scott, K.E., "Self-Paced Laboratory Modules to Support Projects and Independent Study," Event 3272 Preprint, 86th Annual Meeting of ASEE, University of British Columbia, Vancouver (1978).

Seidel, R.J. and Rubin, M., Computers and Communication: Implications for Education, Academic Press, Inc., New York (1977).

Seltzer, Norman, Scientific and Engineering Manpower Redefined: 1972 Postcensual Survey of Professional Scientific and Technical

Manpower; Vol. 1 - Demographic, Educational and Professional Characteristics, NSF 75-313 (May, 1975); Vol. 2 - Employment Characteristics, NSF 76-323 (1976); Vol. 3, Geographic, NSF-76-33 National Science Foundation, Washington, D.C. (1976).

Shapiro, A., et al., Illustrated Experiments in Fluid Mechanics, M.I.T. Press, Cambridge, Massachusetts (1972).

Sjogren, D., Baldwin, L., Jacobson, L., and Birkeland, D., "Studies on the Use of Extramural Videopublished Materials in Continuing Education,: Final Report on NSF Grant HES 75-19854, Colorado State University, Fort Collins (August, 1976).

Skinner, B.F., "The Science of Learning and the Art of Teaching," Harvard Educational Review, Cambridge, Massachusetts, 24, 2 (1954).

Smith, E., "TV or Not TV? That's the Question," Engineering Education, 64, pp. 505-506 (April, 1974).

Starke, J.W., "Will Teachers Be the Next Dodo Birds," Engineering Education, 63, No. 3, pp. 196-198 (1972).

Stice, J.E., "The Personalized System of Instruction (PSI): The Keller Plan Applied in Engineering Education," Bureau of Engineering Teaching, Bulletin, 4, University of Texas at Austin (1971).

Strover, S., "Curriculum-Sharing Via Satellite, Final Report on the Stanford-Carleton-NASA-Ames CTS Demonstration," Institute for Communication Research, Stanford Unversity, Stanford, California (February, 1978).

Stutzman, W.L. and Grigsby, L.L., "A Multimedia Approach to Remote Classroom Instruction," Engineering Education, 63, pp. 119-123 (November, 1973).

Sugarman, R., "A Second Chance for Computer-Aided Instruction," IEEE Spectrum, 15, pp. 29-37 (August, 1978).

Suydam, M.N., "Periodic Newsletter," Calculator Information Center, 1200 Chambers Road, Columbus, Ohio 45212 (1978).

Tickton, S. (ed.), To Improve Learning, Report by the U.S. Commission on Instructional Technology, Bowker Publishing, New York (1970).

Tribus, M., "The Three Faces of Technology and the Implications for Engineering Education," R.P. Davis Memorial Address, West Virginia University (March 17, 1975).

Vesper, K.H. and Adams, J.L., "Evaluating Learning from the Case Methods," Engineering Education, 59, pp. 104-106 (October, 1969).

Vesper, K.H. and Adams, J.L., "Teaching Objectives, Style and Effect with the Case Method," Engineering Education, 61, pp. 831-833 (April, 1971).

Wales, C.E. and Stager, R.A., "The Design of an Educational System," Engineering Education, 62, 456-59, 488, (February, 1972).

Ward, J.C., "Cable Television Hardware: The State of the Art," Proceedings of the Conference on Cable Television and the University, EDUCOM, P.O. Box 364, Princeton, New Jersey (January, 1974).

Ward, R.C. and Maxwell, L.M., "HI-TIE: The University, the High School and Engineering," Engineering Education, 64, No. 4, pp. 325-328 (January, 1975).

Whitney, T.M., "Compact Computers for the 1980's," in Seidel, R.J., and Rubin, M. (eds.), Computers and Communication: Implications for Education, Academic Press, Inc., New York (1977).

Willey, L.V. Jr., "Computers and Instructional Productivity," a Professional Report, International Business Machines Corporation, Bethesda, Maryland (May, 1975).

Wozny, M.J., "Interactive Computer Graphics for Engineering Education," Professional Engineering, 48, No. 6, pp. 14-18 (June, 1978).

Zinn, K.L., "Instructional Uses of Computers in Higher Education," Ch. 5 in Hamblen, J.W. (ed.), The Fourth Inventory of Computers in Higher Education, EDUCOM Series in Computing, No. 4 (1980).

ACKNOWLEDGMENTS

Throughout this report the authors have cited many authorities and provided extensive references to enhance its utility. Appreciation is expressed to all, with specific acknowledgment of the permissions received for reprinting certain tables, figures, and text.

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Appendix C. Ms. Carolyn P. Landis, Secretary to the Corporation, Interuniversity Communications Council, Inc., authorized this reprint of C. B. Bowen's paper, "The University as Videopublisher of Last Resort," from the proceedings, CABLE TELEVISION AND THE UNIVERSITY (1974). EDUCOM is the publisher. The ERIC document number is ED 093 378.

Appendix D. "A Second Chance for Computer-Aided Instruction," by Robert Sugarman is reprinted from IEEE SPECTRUM, August 1978, vol. 15, no. 8, pp. 29-37, with the permission of IEEE.

APPENDIXES

Each of the following four appendixes expands on an important facet of the role of modern technology in engineering education.

Appendix A: A recognized authority on instructional media, Wilbur Schramm, summarizes what he gleaned from a review of many research studies of instructional television (ITV). Schramm concentrates on the way the subject matter is presented and the instructional strategies of ITV, i.e., what the teacher and the producer can do within the program to help viewers learn.

Appendix B: Productivity is an economic concept often used by the makers of public policy. Productivity may also be the most flexible framework for evaluating what ET does when it is applied at the local level.

In 1974, Lawrence V. Willey, Jr., studied operational applications of computing in instruction. The purpose of the inquiry was to define instructional productivity in practical terms and to identify examples in which computing demonstrably improved instructional productivity. This concept is not well understood by educators. Perhaps, these examples will help.

Appendix C is an enjoyable account of the history of textbooks, the first education technology (ET). Viewed in this context, today's educator is more flexible toward ET than usually thought.

Appendix D: IEEE Associate Editor, Robert Sugarman, surveys the status of computer-aided instruction (CAI) in the August, 1978, issue of SPECTRUM. He gives a balanced view of past problems and successes, and focuses on the possible impact of the new "intelligent videodisc."

PAGES 99-112, APPENDICES A AND B REMOVED DUE TO COPYRIGHT RESTRICTIONS.

APPENDIX C
THE UNIVERSITY AS VIDEOPUBLISHER OF LAST RESORT

C. B. Bowen
Cable Television and the University
Proceedings of the Conference
(January, 1974)

THE TRADITIONAL THINGS OF LEARNING

Education has been religious in purpose far longer than it has been secular, and that legacy is important in instructional procedure, and in instructional mediation. The monastery and the cloister gave us campus-based instruction, not the moveable feasts of itinerant scholars and their students (the medieval open university, if you please) but fixed instructional plant, high walls, trees, and residences for scholars and students. The tutorial emerged directly from catechism; indeed the magic classroom size (30) emerges from Talmudic instruction, as Alvin Eurich has stated.[2] As it was with the campus, and with the lecture, so it was with instructional things. The substance of learning was recorded by the prevailing labor-intensive technology, and the scribes devoted lifetimes first to accurately copying the text and later to embellishing the page.

Perhaps the immediate ancestors of university publishers were these scribes attached to monasteries, charged with the obligation to preserve the precious libraries of handwritten books by making meticulous handwritten copies, often adding decoration and embellishment. The copying of text was done with great care, exhaustively proofread (for errors might involve heresy), then given headings and title pages of suitable graphic grandeur, and, finally, bound. The glorious era of handwritten manuscripts and bound books was a massive step forward from previous devices for preserving thought and carrying it over distances in time and space; and the orderly procedures of proofreading and editorial care which were then followed continue to this day to preserve a text from one time and place to another.

The first textbooks – that is to say, those works studied or consulted in the process of instruction for whatever purpose – were copied books; they correspond to the modes of encoding then prevalent, but were not widely used. They were costly, cumbersome, perishable, and for all these reasons, access to them was highly restricted. It was the lawyers, who consulted text far more than the churchmen, who for reasons of convenience first changed the structure of written compilations from the roll to the book as we know it, with pages bound along one edge.

If the scribes were the scholarly publishers of their day, the antecedents of the publishers of textbooks may be found in the university students of former times who sought to provide their own low-priced copies of the classics. The historic role of the teacher in an early university was to read aloud from the classics at dictation speeds to gatherings of students. Rashdall, the great historian of medieval universities, suggests that the lecture then came to be divided into two parts: first, the reading of the text so that students could copy it, and second, selections of the most significant passeges within the text and commentary upon them. Later Odofredus, lecturing (the word dervies from the Latin, *legere*, to read) at Bologna in the early thirteenth century, augmented the dictated text as follows: "First, I shall give you summaries of each topic before I proceed to the text; secondly, I shall give you as clear and explicit a statement as I can of the purport of each Law; thirdly, I shall read the text with a view to correcting it; fourthly, I shall briefly repeat the contents of the Law and any distinctions or subtle and useful problems arising out of the Law with their solutions.[3]

Students, as enterprising then as now, quickly came to make arrangements with stationers who for a fee copied lecture transcriptions, or booksellers who rented out copies of full sets of transcriptions for the year. So much for the Italian line of descent for our textbook publishing. The other great university of that time, Paris, ". . . had its own statute on lecturing. Here the intention is to prevent the student from taking full notes – to prevent the publication and distribution of the [illegible] property: A later statute indicates the reaction of the students [to this early application of the principles of copyright]: 'scolars who throw stones at masters who speak too rapidly are to be fined.' "[4] The genealogy of textbook publishing thus had a proper combination of Italian enterpreneurship and French concern for proprietorship; it remains only to observe that so little changes with time.

As I have noted, education has been religious far longer than it has been secular. To the educational monopoly of the early Church, the monastic schools, that secular substance came first in the Norse sagas, the *Song of Roland*, and the *Nibelungenlied*; and finally into this cleft marched the whole of the classical past – Greek philosophy, Roman law. The medieval university, a scholastic institution embracing both the Christian and the classic past, was born. Its masters and students, bound by religious observation and practice, lived communally. It was poor, but portable; and although relatively free from constraining forces of the church, the state, or the local populace, such fragile institutions were given sanction by both pope and emperor, which meant that a degree from any one institution was acceptable throughout Western Europe. Teachers, students, and indeed, whole institutions, could move at will from place to place. The substance of the programs of these universities is of less concern to us than their teaching methodology, and, most pertinent, their use of instructional materials. For all faculties – theology, law, medicine, and philosophy –

> . . .The method was the same. In theology it consisted in acquiring the summa, the total body of the logical knowledge gradually worked out in the system of the theological doctors. In medicine, it was the learning of the medical body of knowledge laid down in the system of the Hippocratic-Galenic tradition. In jurisprudence, the student learned the body of the Roman and Church law. And in the philosophical faculty there was a regular body of Aristotelian and mathematical knowledge which was considered authoritative. In a word it was the textbook method. The books were meticulously

divided into puncta (periods?), and professors were fined at Bologna if they did not reach the proper points at the proper time.[5]

Thus, working through a subject, relieved regularly by discussion, and after rigorous examination (the baccalaureate examination at Paris lasted some televe hours, through which the candidate remained standing), a student moved to his successive degrees. Specialities developed; one went to Salerno for medicine, Bologna for law, Paris for theology. But the full flowering of instructional use of the conserved word awaited the invention, or at least the application, of the new technology of movable type.

An historical view of the evolution of the textbook illumines the universe of other instructional things. From the beginning, the textbook offered substance, that body of learning was to be conveyed across time and space from mentor to student. But it also came to offer a structure, the instructional strategy of presentation. The textbook was, and is, a highly ordered learning instrument; it presumes a curriculum and conserves its subjects' place therein. It creates a lesson plan or syllabus to guide both teacher and student. It offers interaction, through questions and answers, study or research assignments, suggestions for further reading and integration of further reading with the text. And increasingly it came to offer evaluation, self-administered examinations to quizzes, to help the student find his way through the lesson. If the elements sound familiar – substance, structure, strategy, performance measures – it is because the textbook from mid-nineteenth century America to much of the world today constitutes not merely the foremost, but the solitary instructional "thing" used by most teachers. Teachers have been trained to use textbooks; they enjoy the freedom to chose or select among many optional texts; they may adapt their course work from greater to lesser conformity with the substance and arrangement of a given text; and, critically, they hold the prospect of creating their own text if none exists to serve the course as they wish to teach it.

Contrast this with the circumstance facing visual (read video) courseware or textbooks: Teachers are not trained to use non-print instructional stuff. There is little organized distribution and supply of non-print material. An instructor is constrained to use the non-print material as given, if at all, and further constrained in time, place, physical circumstance, and other logistical concerns. Further, if no such material exists for his course, he is constrained by skills and cost from creating his own; it is as though each instructor who wished to write a textbook were obliged to take his ideas to the bazaar and hire a scribe to set down the text, and then never see mass reproduction of the copy, but rather other handwritten copies.

Thus, the elements which have defeated instructional television and frustrated the full visual and textual presentation of subject matter, whatever the field of study, are still with us. We have infinitely increased the speed and flexibility of text copying; from moveable type, the invention of the typewriter, the production of mass market editions of texts, and the growth of better copying devices, text and graphic presentation of subject matter have been vastly enhanced. The constraints upon the non-print media, constraints of entrepreneurship, proprietorship, originating or authoring competence, mechanisms for inexpensive reproduction, widespread distribution, and resulting economics of scale resulting in lower cost – all these still constrain lie the non-print media.

REFERENCES

2. Eurich, Alan C.: oral communication
3. Rashdall, Hastings: The Universities of Europe in the Middle Ages; Oxford, 1936, Vol. I, p. 218
4. Fehl, Noah E.: The Idea of a University in East and West Hong Kong; Chung Che College, 1962; p. 188
5. Mueller, Gustav E., Education Limited; Norman: University of Oklahoma Press, 1949, p. 129

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